PRODUCT ENGINEERING

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McGRAW-HILL PUBLISHING CO., INC. JUNE 1937 VOLUME EIGHT, NUMBER SIX

Science Is Never Defeated

HOW LITTLE the layman knows of the spirit that animates the scientist! No sooner had disaster overtaken the Hindenburg than editorial writers and legislators intoned a litany over the ashes and bemoaned another defeat for science.

A cartoonist drew a striking picture of a dejected looking man gazing at the plans for an airship. In the background could be seen the Akron, the Macon, the Roma and the Shenandoah, each at the moment of its destruction. The cartoon carried the title "Another Defeat."

Science is never defeated. It is baffled—many times. It makes innumerable failures, encounters countless disappointments. But these are incidents, regrettable perhaps, that point out errors in logic, in judgment, in observation. Science learns from them, and seldom makes the same mistake a second time. Each failure contributes something to our general fund of knowledge, something that can be entered in the records to prevent our successors from repeating the mistake that caused it, or else stimulating them to think of a way to avoid it.

During the past few months we have killed too many people in airplane crashes. The number has been few compared to the total number of airline passengers, but we must find out how to bring all planes down in safety. In most of these failures science has outrun the human element. It has provided means of communication that have permitted us to fly under conditions that would have been prohibitive only three or four years ago. But in so doing it has put too great a strain on the pilot, and has opened the way for airline directors to send planes up when discretion would keep them on the ground until weather conditions improved. Several of the crashes have been attributed to failure of the pilot. Either he did not know definitely where he was or he was not warned of some unusual atmospheric condition like the icing up of ailerons that put at least one wrecked ship out of control.

These mechanical faults will be corrected. Better understanding of the physical strain involved in flying and landing a modern high-speed transport plane will lead to rules of procedure that will reduce the likelihood of human failure. The Hindenburg disaster would not have occurred if helium instead of hydrogen had been used. Many have criticized the Germans for persisting in the use of hydrogen but they forget the remarkable record of performance with hydrogen-filled ships that stands to the Germans' credit. Captain Pruss, for instance, had made 170 Atlantic crossings.

The loss of the Hindenburg is a sad blow to science and engineering. It was a frightful disaster, but it is not a defeat.

All incoming material is sent directly to the Librarian for classification and distribution

CARD FORM SYSTEM

for Filing and Locating Drawings

J. J. CALHOUN
Body Engineer, Edward G. Budd Manufacturing Company

Engineering drawings and records are quickly found and collated by use of system having a numerical code which designates both main and sub-group division or heads

MUCH futile searching and time wasting interruptions from useful activities are caused by the inability at times to locate quickly a drawing of a part, probably properly filed, but temporarily lost in storage because indexes covering the system are not definite and specific.

Unfortunately from the viewpoint of efficient operation, many systems now in force for cataloging and filing engineering drawings have outlived the particular needs which they were devised to satisfy. In the course of time the types of products manufactured change thus increasing the volume and kinds of items that need to be indexed and soon one finds that the base of the system is too narrow in scope to meet the new demands. When this situation occurs it is very difficult to make amendments or to inaugurate sub systems without introducing complications that become cumbersome and that destroy all semblance of a logical arrangement.

In most efforts to be thorough there is a tendency to set up too much system that results in keeping records that are seldom looked at after filing. Needless to say time is wasted in keeping data of that sort. Only when a system is a direct aid in saving effort or material is its cost of operation economically justified.

In general, the operations performed in connection with cataloging and indexing engineering drawings are similar to those carried on by a circulating library. All incoming material and that produced by the department must be cataloged and indexed, material circulating in the department must be recorded with notations as to where it can be found, and inactive material filed so that it can be quickly located.

A great many otherwise good systems

pay little attention to customer's prints and data. The practice should be discouraged of turning customer's information over to an engineer or draftsman without previously recording its receipt and then later assembling in a bundle what pieces can be found and placing them haphazardly in a storeroom.

A method believed to be unique, has been in use at the E. G. Budd Company for classifying, indexing and recording company drawings, customer's drawings and correspondence in one system. It has been in use some twenty years and has been found to be satisfactory in every way; it is comprehensive, flexible and can be operated quickly.

Complete authority and responsibility for the operation of the system is delegated to a librarian. All customers' blueprints, together with such correspondence as contains engineering information, when received, are routed to the librarian's desk. Here every piece is immediately stamped by hand on the reverse side in the lower right-hand corner. Fig. 1 shows the form imprinted.

DATE May 5 1937	FILE NO.
TITLE	
CUST. NO.	BUDD NO.
CORRESPONDENCE	PREVIOUS FILE NO.

Fig. 1—Each blueprint and letter received by the engineering department is imprinted with this form in which the file number is noted

Next on a 5x8-in. card form, entitled "Record of Outside Prints," shown in Fig. 2, for each print received a running entry is typewritten opposite a serial number showing order of receipt, date received, name of customer, name of print and customer's part number. The serial number which indicates the order of receipt at once becomes the file number and is noted in pencil in that space in the stamped form on the back of the print. If correspondence is received with the print the date of the letter is indicated in the box marked correspondence, the drawing file number also is written in the form on back of the letter. By means of this simple device a record that both exist is made on the letter and print; it also indicates that fact to the person using either piece.

To facilitate locating an entry when searching back through the file of "Record of Outside Prints" cards, the first serial number used on each card is divisible by ten and contains ten entries. This is an important consideration since from 600 to 900 outside prints are handled per month.

The librarian also maintains a customer's part number file on 3x5-in. cards, shown in Fig. 3, on which is entered the name of the part, customer's name, customer's part number, number required per assembly, where used, and a classification number made up from a code. These cards are filed in numerical sequence according to the customer's part number. No differentiating is made by customer's name. All are put together in one file and arranged in sequence only by part number. It may happen that more than one customer uses the same number to identify his part and that the parts may be unlike each other. However, other information on the card will identify each particular piece. In this way it has not been necessary to carry a cumbersome and irregular classification and indexing of customers' information.

RECORD OF OUTSIDE PRINTS

OUR No.	DATE REC'D	NAME OF COMPANY	NAME OF PRINT	THEIR No.
99410	5-5-37	Studebaker 7-A, 8-A, 4-C	Body Side Panels	266670-1
99411	5-5-37	Packard 1189,1199	Door Hinge Reinf.	325854-5
99412	5-5-37	Studebaker 7-A,8-A,4-C	Body Side Panels	266670-1
99413				
99414				
99415				

Fig. 2—Form card used for making running entries showing receipt of customer's prints

Corner of the drawing storage vault, on the left folded outside prints are filed by number. Rolled tracings are filed in tubes and flat pieces are kept in cabinet drawers

Use of Code Numbers

The code consists of ten key numbers, beginning with 10,000 and ending with 100,000 in increments of 10,000, thus 10,000; 20,000; 30,000, and so on. Each key number designates a general group or main division of breakdown, such as piece drawings, factory maintenance, outside part prints, and so on. A sub group code is also used that designates the kind of a part or assembly that is shown on the drawing being classified. In the sub group code the numbers from 1 to 10,000 are broken up into 26 blocks not necessarily equal in size. One block is assigned to each letter of the alphabet in this fashion, for A is assigned 1 to 399; for B, 400 to 799; for C, 800 to 1199, and so on. On the code list under each letter is listed the names of parts which begin with that letter, one for each number. In coding the names of parts in the sub group no effort is made to list them in alphabetical order; numbers are assigned as needed, thus under A the numeral 1 is assigned to angles, 2 is assigned to arms, 3 to axle, 4 to apron, and so on.

A number on the right-hand side of a decimal point is used to identify a particular part in its own subdivision. This number is assigned in numerical sequence after checking with customer's part number file to determine if the part has been cataloged previously. If the part has been cataloged before, the file number of the new print is entered

on both the existing customer's part number file card and the classification number card, and the previous file number on the back of the print. If the particular part has not been cataloged before, but other similar pieces have been, then the next sequence number is assigned to the right-hand side to complete the classification number.

Classification Numbers

In building up a classification number for a part the above elements are used. Assume that the part in question is an axle shown on an outside print and that it is the 14th axle to be classified. The key number for outside prints is 70,000, and the sub group number under A, for axle, is 3. These three numbers added together give 70,003.14 as the classification number.

A classification number file indexed numerically is also kept by the librarian on 3x5-in. cards like that shown in Fig. 4, on which is typewritten the classification number, part number, description of the part and file number referred to in the preceding paragraphs. With this system of classification all cards covering the same type of part are together in the file, making it very easy to locate the part when searching.

After these entries are made the customer's prints are delivered by the librarian to the engineer or draftsman who is in charge of that particular job, and gets a receipt from the person to whom they are delivered. The receipt is then sent to the clerk in charge of filing and storage of drawings, and is filed by serial number. This receipt is surrendered when the print is delivered to the storage cage for safekeeping. Here the print is folded to dimensions approximating 9x12-in., in such fashion that the space on back stamped by the librarian when first received is uppermost with the imprint visible and is then filed vertically by file number.

Drawings of one size are filed together. Our own drawings and tracings are made in six standard sizes which are designated by letters, the largest sizes are rolled and kept in tubes and bear the symbol T. Other sizes which can be filed flat are called, A, B, C, D or E drawings. One of these letters is used as the first symbol in the drawing number, the numerical part of the symbol is without particular significance since it is assigned in the order of completion regardless of size of drawing.

Notations are made on the drawing number list, which include the customer's name, his part number, and name of part. The drawings excepting assemblies, show only one piece, therefore the drawing number can be and is used as a part number for reference and manufacturing records. The librarian receives notice of the assigned drawing numbers and enters them on the cards in the customer's part number file.

With these records it is a simple matter to collate information concerning any item. The classification number for the part, which, after working with the system for a short while, can usually be constructed mentally from memory, and always by means of the code book, is the key to the system. The file cards being arranged numerically, the classification card can be quickly located to obtain a customer's part number and file number of customer's prints with notations covering correspondence, if any.

Customers' Drawings

Then by using the customer's part number file, that card, when found, will give our own part number, which is our drawing number. Usually this is all the information needed to locate any drawing made by ourselves or received from outside.

When our own part number only is known, reference to the numerical system for numbering drawings, or to the drawing itself, will indicate name of part and customer.

Customers' drawings are checked very carefully with full-size assembly layout for size, contour and adjacent mating surfaces. When new models are brought out or developed they are laid out full size on aluminum sheets to avoid any change in the dimensions or shape of drawing because of temperature and humidity variations.

The metal sheets are 66 in. wide and 14 ft. long, and about 1/16 in. thick. One surface is prepared by applying to it several coats of white paint which is rubbed down smoothly for a drawing surface. This is placed painted side up on a large heavy table. A straight base line is drawn near the bottom edge in red ink, and from this are erected perpendiculars every ten inches across the plate, also drawn in red. Then a series of lines ten inches apart, parallel to the base line, are drawn, which divide the plate into accurately dimensioned and constructed squares. Steel straight edges and triangles are used by the draftsmen. All points and offsets are located by measurement from the squares and connecting lines are drawn in with the straight edges or splines.

Working drawings are constructed by lifting measurements off the cross and longitudinal sections delineated on the metal draft. Often a part can be traced directly from the layout. The metal drafts serve as master drawings and templates. They are filed and kept until the model is discontinued.

When making up parts lists, great care is exercised to list the parts in the sequence of assembly, because frequently parts will assemble in only one order.

To help the shipping departments to easily identify parts, isometric or perspective drawings are issued which show the characteristic profiles, features and particularly the overall dimensions of parts so that space and packing arrangements can be estimated for carloading.

DATE 5-5-37 BUDD PART NO.
NAME Body Side Panel CUST. PART NO. 266670-1
Studebaker
NO. REQ. 1 98
USED ON 7-A, 8-A, 4-C Sedans
CLASS NO. 76001.125 FILE NO. 99410 99412
Draft 394 Budd EDW. G. BUDD MFG. CO. - PHILA., PA.

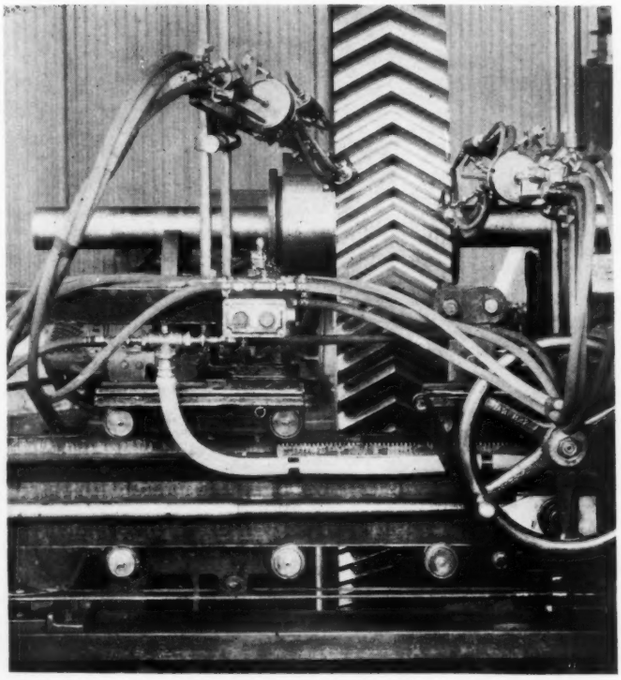
Fig. 3—All customer's part number information and data is filed in one numerical system

Form Draft 843 Budd
CLASS NO. 76001.225 PART NO. 266670-1
DESCRIPTION Body Side Panels
Studebaker 7-A, 8-A, 4-C Sedans

	FILE NO.	DATE		FILE NO.	DATE
A	99410	5-5-37	F		
B	99412	5-5-37	G		
C			H		
D			I		
E			J		

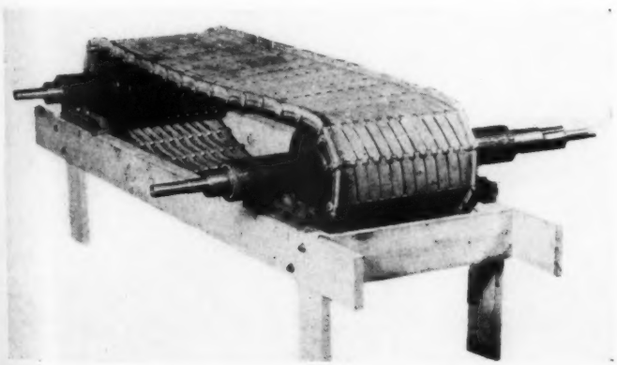
Fig. 4—The classification number card is the key to the entire system, it shows all necessary information for locating prints and drawings

Product Developments

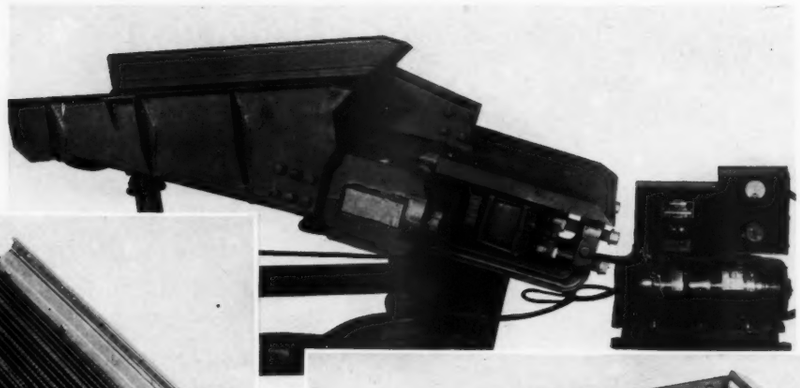


Four-Torch Gear-Hardening Machine—Two separate torch heads, each carrying two sets of torches and attached water jets, enable the machine to harden both sides of a gear tooth or both helices of a double-helical gear simultaneously. In hardening double-helical gears, the torch heads start at opposite ends of the tooth. They travel toward the center or apex of the gear tooth on a horizontal traverse. At the same time a guide roller mounted on the torch carrier and engaged between two teeth of the gear causes the latter to revolve so that the helical trace of the teeth is kept in correct relationship to the horizontal traverse of the torches. The machine, although especially designed by Farrel-Birmingham, Inc., Buffalo, N. Y., to harden double-helical or herringbone gear teeth, is equally well adapted for use on single-helical or straight-tooth gears, splines, sprocket wheels and similar parts.

Grinder Wheel Load Shown by Built-in Ammeter—Flush-mounted just above the feed controls, the ammeter on the Blanchard Machine Company's No. 18 vertical surface grinder gives the operator a visual indication of what his wheel load is at all times. By permitting comparison with the full-load motor current, this feature eliminates the possibility of using such fine feeds as to prolong grinding time unduly. It warns the operator of overloads, showing their extent, continuity, and frequency. With it, an experienced operator can detect a dull wheel or loading, and is guided in the economical use of his dressing attachment. In extreme cases, the instrument may reveal electrical irregularities in starting, stopping and plugging relays, or high-resistance and dirty pushbutton contacts. Line voltage disturbances are very evident.



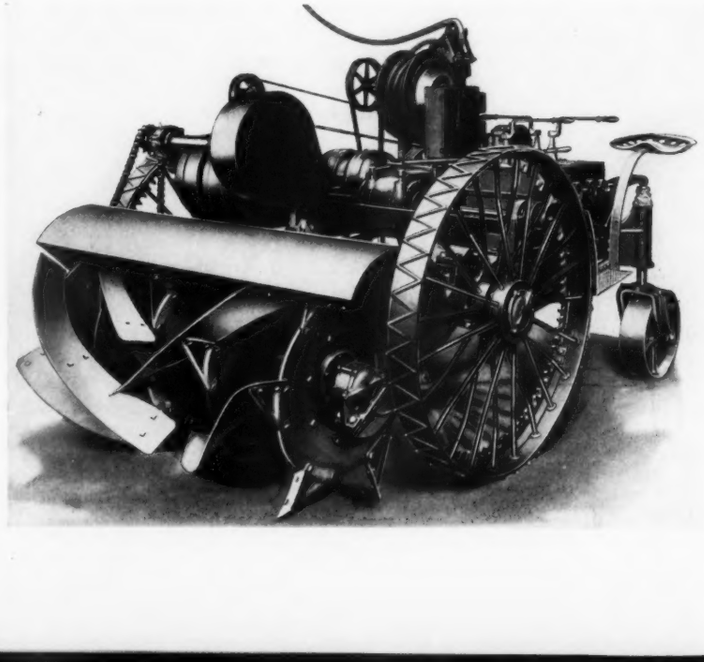
High-Temperature Conveyor Belt—Each link is one spiral casting extending entirely across the width of the belt which, designed primarily for industrial furnaces, has been developed by the General Alloys Co., Boston, Mass., for applications up to 2,000 deg. F. Made of the company's Q-Alloy metal, the links are hinged together by long pins which also extend the width of the belt. The construction is such as to equalize the load on the pins, permitting the use of a lightweight design without danger of breaking. When assembled, the openings in the top surface are small and the belt which does not stretch, presents practically a solid surface for conveying the work. Its weight is approximately 15 lb. per sq. ft. for average loads and belt widths.

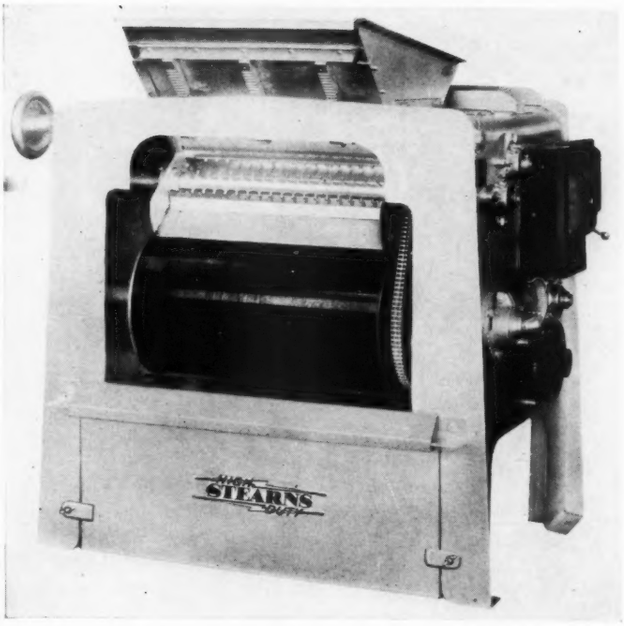


Electro-Magnets Reduce the Number of Moving Parts — Designs of screens and feeders using electro-magnets as the actuating element have been simplified to a point where there is virtually only one moving part. In the vibrating feeder of the Jeffrey Manufacturing Company shown at top above, powerful electro-magnets serve as a vibrating motor. Electrical impulses through the magnetic circuit create a succession of magnetic pulls on the armature. Opposing the pull of the magnets is the restoring force of heavy leaf springs. The armature never comes in contact with the magnet and the springs are designed so that their frequency conforms to the frequency of the alternating current.

Modification of this design is to use a.c. superimposed upon d.c. to increase the intensity and duration of the magnetic waves. In either instance, the frequency of vibration is determined entirely by the frequency of the current and the amplitude of the vibration is determined by the magnitude of the current. As can be seen in the illustration of the Jeffrey unit, a small motor-generator set with rheostat controls furnishes the power. At the right above is shown a similar feeder built by Allis Chalmers which, however, employs dual magnets permitting the magnetic forces to be applied equally in both directions and thereby eliminating the necessity for storing energy by means of springs or similar devices. At the left above is shown a single deck electro-magnetic screen operating on the same principle, also a product of the Allis Chalmers Manufacturing Company.

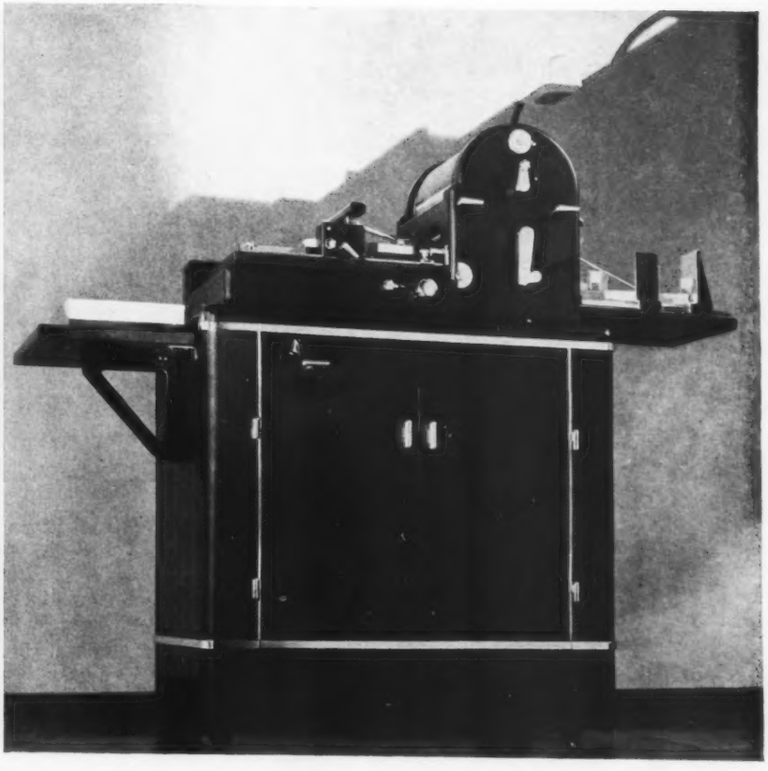
Multi-Motor Operation Simplifies Unit Drives — Four independently controlled electric motors are used in the operation of the Type M sand cutter designed and built by the American Foundry Equipment Company. One motor drives the cutting cylinder, another drives the winch for raising and lowering the cutting cylinder, the third motor drives the cable reel, and the fourth drives the machine. Each of these motors drives through reducing gears. The motor for driving the vehicle transmits its power through a worm reduction and bevel gear reversing unit. This enables either wheel to be driven in either direction, thereby steering the vehicle. Other features of this heavy-duty unit are the flexibility of the design of the frame, high axle clearance, and compact design which results in the overall width being only 19 in. greater than the cutting cylinder length. All ball bearings are sealed.



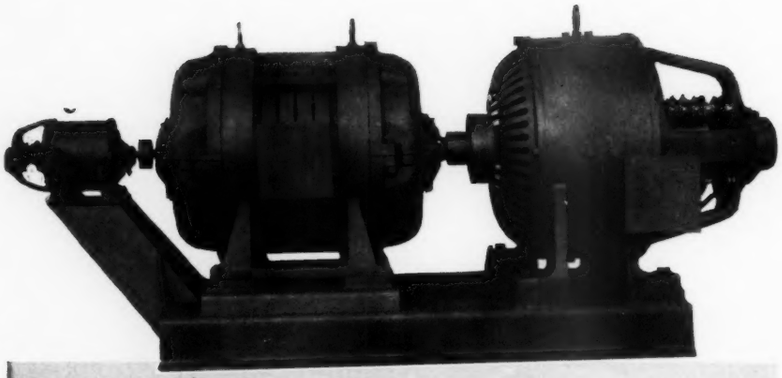


Self-Contained Drive for Magnetic Separator — Several new features are incorporated in the new magnetic separator designed by Stearns Magnetic Manufacturing Company. The drive is entirely concealed and protected for the purpose of not only providing complete safety for the operator but also improving the appearance. Anti-friction bearings are used throughout and the transmission is roller-chain.

Cableless Spot-Welding Gun — Hydraulically operated, the new portable spot-welding gun made by the Progressive Welder Company, Detroit, Mich., eliminates the use of conductor cables by utilizing the upper pressure bar as a combined conductor bar and back-up support, the lower bar providing the other lead to the transformer. It also has an off-center design of piston mounting in order to decrease arcing and flaring at the welding points.



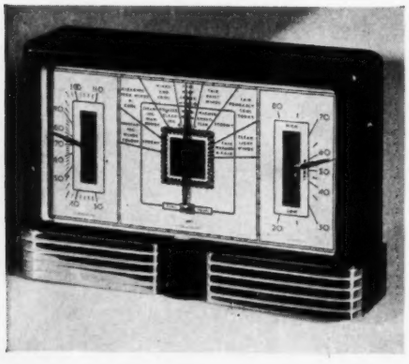
Only Yesterday It Looked O.K. — But today the appearance of the old Mimeograph suffers in contrast with the organized design of the new model, with its convenient, accented controls grouped in natural range of the operator's hands and practically all internal moving parts concealed within the housing. The sturdy steel stand, acoustically treated, encloses the motor drive and provides convenient storage space. A new free-wheeling feature permits turning the cylinder without either disengaging or dragging the motor. Designed by Walter Dorwin Teague.



Welded Motor-Generator Base — Smoothly rounded contours and V-shaped reinforcing ribs are the principal design features incorporated in the electric-arc-welded base that has now superseded cast-iron bases on Reliance Electric & Engineering Company's motor-generator sets. The ribs are provided to increase strength and avoid distortion, and the design results in a 15 percent average reduction in weight of the bases despite the fact that they are considerably stronger than those made of cast iron. The top, sides, and base flange are each pressed from a single sheet. The material used for the ribs and for the top and side plates is a heavy-gauge special pressing steel. As an additional precaution against distortion, all welds are stress relieved after completion.

Bigger and Bigger—Measuring 26½ in. in diameter and 11½ in. in depth, the new 1,000-watt reflector shown is the largest plastic piece ever produced. Molded of Plaskon by the General Electric Company for the F. W. Wakefield Brass Company, it has an area of 550 sq. in., nearly twice that of the Toledo scale housing which held the previous record. Designed by Harold Van Doren.

Three-Purpose Instrument—With temperature and humidity indicators included to widen the function of its former Stormoguide, the Taylor Instrument Companies' new combination instrument has a one-piece phenolic plastic housing of Durez which provides a pleasing contrast with the chromium-plated bands running horizontally across the base.



RANDOM JOTTINGS ABOUT NEW DEVELOPMENTS

A new diesel-engine starter, consisting of a small four-cylinder gasoline engine with magneto ignition and hand crank and a V-belt drive, has been designed by the Hercules Motor Corporation, Canton, Ohio. Besides eliminating batteries, the small engine warms the diesel to make starting easier.

Circulating water from the starter engine is pumped through the cylinder block of the diesel and the exhaust from the former is piped around the intake manifold of the latter. Because of its shock-absorbing characteristics, the V-belt is used to provide a positive but flexible drive between the clutch on the starter engine and the pinion turning the flywheel ring-gear on the diesel.

★ ★

To prevent the scraper blades which bear against the polished rolls in a dough-mixing machine from scratching the roll surface, a welded-on edge of Haynes Stellite is now being employed for the scrapers. Previously, steel soft enough to eliminate scratching was also tried but it wore out too rapidly. The low coefficient of friction and high polish of the alloy now used solves the scratching problem while its wear-resistant characteristics contribute to the desired long life for the scrapers.

★ ★

A safety bath tub, the bottom of which is embossed to reduce the hazard of slipping or skidding is pressed from ingot iron instead of being cast iron. The press is of the crankless type and exerts a pressure of 1,500 tons. A production of 53 bathtubs per hour is possible.

WORKING STRESSES

for Loaded Members Affected by Creep

JOSEPH MARIN, *Rutgers University*

Experimental observations show that creep often is of such magnitude as to be the controlling factor in determining allowable stresses in members under axial and compound loads

MACHINE and structural members which are simultaneously subjected to stresses and to high temperature develop with time a plastic deformation or creep. This creep is often of such magnitude that it is the governing factor which determines the working stress to be used in a design.

This discussion will be confined to examples where creep is important. No reference will be made to conditions in which the temperature is operating at small intervals of time compared to the life of the member, for then it is only necessary to determine the yield or proof stress for the material at the maximum operating temperature and to divide this stress value by an appropriate factor of safety. Where creep is important, however, the problem is more complicated.

For the design of a member subjected to an axial tension at a high temperature accompanied by creep, the designer must know a working stress value. Such a stress which, for the particular operating temperature, will produce a total deformation during the estimated life less than some predetermined value. Another way of stating this working stress is to define it as a stress which produces a limiting average creep rate, that is, a selected unit deformation per unit time.

There has been much experimental work to determine such working stresses or creep limits for various metals. A Joint Committee of the American Society for Testing Materials and the American Society of Mechanical Engineers have spent considerable effort on this problem. Many interpretations of experimental data to determine these working stresses have been developed. For the most recent see: "Working Stresses," C. R. Soderberg, A.S.M.E. *Trans.*, Vol. 55, p. 131, 1933; "The Interpretation of Creep Tests," P. G. McVetty, *Proc.* A.S.T.M., 1934 also A.S.M.E. *Trans.*, Vol. 55, p. 99, 1933 and *Mechanical Engineering*, March 1934, p. 149; and "Design Aspects of Creep," R. W. Bailey, A.S.M.E. *Trans.*, 1936, and also "Utilization of Creep Test Data in Engineering Design," *Proc.* Inst. of Mech. Engrs., London, 1936. Although the methods of interpretation used by Soderberg and McVetty are more exact, the interpretation used by Bailey and others will be used in this article. The justification for this is that it is a good approximation and that it affords a method of defining working stress for conditions of combined stresses.

Using this approximation, the working stress S for an operating temperature t in deg. C is satisfactorily defined by

$$C = AS^n \tag{1}$$

where A and n are experimental constants for the particular temperature considered and C is an average constant allowable plastic unit deformation per unit time (the creep rate). A more general relation for any temperature t in deg. C. suggested by Bailey and which compares favorably with his experiments is

$$C = a\,\varepsilon^{bt}\,S^n \tag{2}$$

where a and b are experimental constants for the particular material and ε is the base for natural logarithms. For purposes of comparison with Bailey's experiments, shown in Fig. 1, it is convenient to write Equation (2) in this form:

$$t = \frac{n}{b}\log \varepsilon S + \frac{1}{b}\log \varepsilon \frac{C}{a} \tag{2a}$$

This is derived by taking the logarithm of both sides of Equation (2). Using the experimental data for 0.4 per cent carbon forged steel tested by Bailey, the experimental constants in Equation (2a) can be determined such that the working stress S is completely defined for a temperature t deg. C. and for a creep strain of 0.001 in 100,000 hours. Then

$$t = 523 - 23.9 \log \varepsilon S, \quad \text{or } S = \varepsilon^{19.4 - 0.037\,t} \tag{3}$$

A plot of Equation (3) is shown in Fig. 1, namely, the values of the working stress S for various temperatures t in deg. C. A comparison with the experimental points shows that this empirical relation is a good approximation. This diagram for working stress applies for a specified allowable creep rate C, and should be so noted.

Combined Stresses

With the working stress defined for axial tension a basis is established for considering the more general case of combined stresses.

Two theories have been formulated

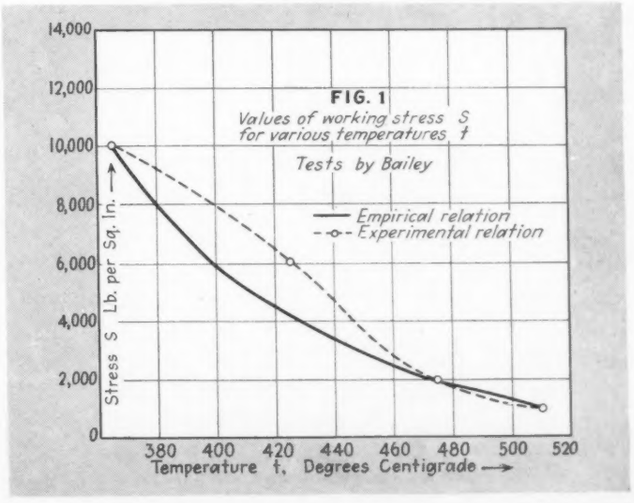


Fig. 1 — Comparison of experimental points with results of empirical equation showing close approximation

for determining creep values for combined stresses. One formulated by Bailey and another based on the work of St. Venant and stated by Soderberg. (See "Discussion" of paper by Bailey on "Design Aspects of Creep," A.S.M.E. *Trans.*, 1936). A comparison of these two theories with experiments and a comparison of designs based on each by the writer shows that both theories are equally in agreement (See "Design of Members Subjected to Creep at High Temperatures," *Journal of Applied Mechanics*. A.S.M.E., March, 1937). The Soderberg or St. Venant theory, however, is more easily applied and for this reason is recommended in this article. It should be noted, however, that there has been little experimental work on the problem of combined stresses accompanied by creep. Reference should also be made of a more recent modification made by Soderberg in which a more accurate formula than Equation (1) is used as a basis. (See "The Interpretation of Creep Tests for Machine Design," C. R. Soderberg, *Trans.* A.S.M.E., Nov., 1936). For sake of simplicity this modification will not be considered at this time. A statement will first be made of the simpler Soderberg or St. Venant Theory, so that working stresses can be formulated for combined stresses.

In general, combined stresses can be completely defined by the three principal stresses S_1, S_2, and S_3. Furthermore, let the creep rates in the direction of these stresses be respectively C_1, C_2 and C_3. Then it will be considered necessary in a design that these creep rates be equal to or less than the allowable creep rate C in simple tension. It is also necessary to determine the values of the creep rates C_1, C_2 and C_3 in terms of the principal stresses. To do this a hypothesis must be assumed. This is analogous to the formulation of a failure theory for static loads at normal temperatures (See "Working Stresses for Members Subjected to Compound Loads," J. Marin, *Product Engineering*, May, 1937). This relationship between creep rates and stresses is made by the Modified St. Venant or Soderberg Theory based on the assumptions:

(1) That the directions of the principal creep strains coincide with those of the principal stresses at all times.

(2) That the volume of the material remains constant.

(3) That the three principal shear creep strains are proportional to the principal shear strains.

(4) That the rate of dissipation of shear energy for simple tension is equal to that for combined stresses.

Based on these assumptions it can be shown that the creep rate C_1 in the direction of the stress S_1 is

$$C_1 = \frac{A}{2^{\frac{n+1}{2}}} \times \left[(S_1-S_2)^2+(S_2-S_3)^2+(S_3-S_1)^2\right]^{\frac{n-1}{2}} \times \left[(S_1-S_2)-(S_3-S_1)\right] \quad (4)$$

where A and n are the experimental constants as in Equation (1). Similar expressions can be written for C_2 and C_3 by replacing subscripts in the second term of Equation (4), namely

$$\left[(S_2-S_3)-(S_1-S_2)\right] \text{ for } C_2,$$

and $$\left[(S_3-S_1)-(S_2-S_3)\right] \text{ for } C_3$$

With the creep rates expressed in terms of the principal stresses, it is now possible to determine working stress values.

Working Stresses

For simplicity the procedure of determining working stresses will be considered for the two-dimensional condition of stress. Then $S_3 = 0$ in Equation (4) and

$$C_1 = \frac{A}{2}\left[S_1^2 - S_1S_2 + S_2^2\right]^{\frac{n-1}{2}}\left[2S_1 - S_2\right] \quad (A)$$

If the allowable creep rate for simple tension is $C = C_w$ then from Equation (1) the corresponding working stress value is $S = S_w$ and

$$C_w = AS_w^n \quad (B)$$

For the allowable creep rate to be the same for combined stresses and simple tension, the allowable value of C_1 is $[C_1]_w = C_w$ and

$$[C_1]_w = AS_w^n \quad (C)$$

Placing this value of C_1 from Equation (C) in Equation (A), the working stress value S_w for the condition of combined stresses is

$$S_w = \sqrt[n]{\frac{1}{2}(S_1^2 - S_1S_2 + S_2^2)^{\frac{n-1}{2}}(2S_1 - S_2)} \quad (D)$$

considering $S_1 > S_2$ Equation (D) can be written

$$S_1 = \frac{S_w}{\sqrt[n]{\frac{1}{2}(1 - R + R^2)^{\frac{n-1}{2}}(2-R)}} \quad (5a)$$

where $R = S_2/S_1$.

In this way the working stress value of S_1 is the quantity on the right side of Equation (5a). It is the working stress

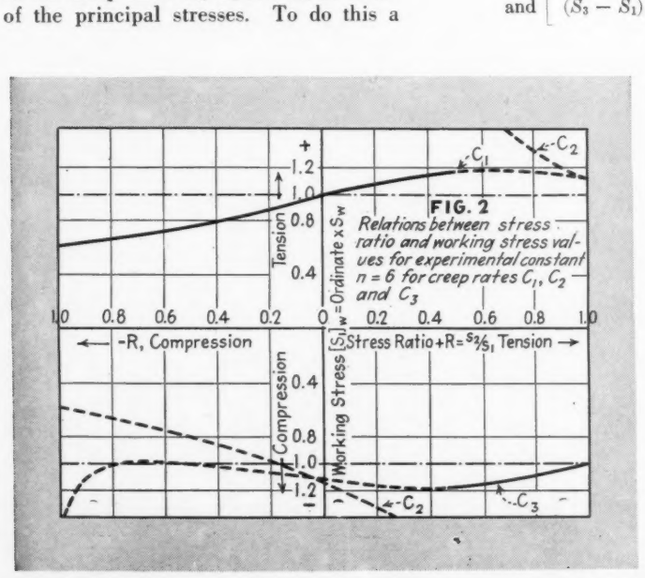


Fig. 2—Diagram showing critical creep rates for values of working stress ratios

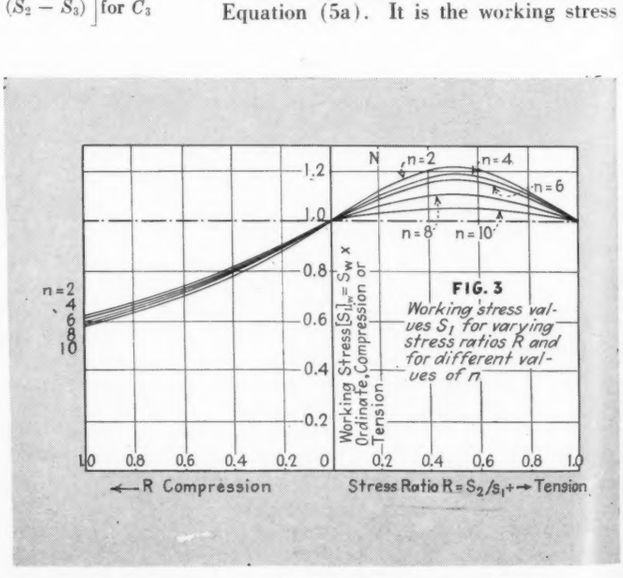


Fig. 3—Variation of "n" makes little difference in the working stress values where the principal stresses are of opposite signs

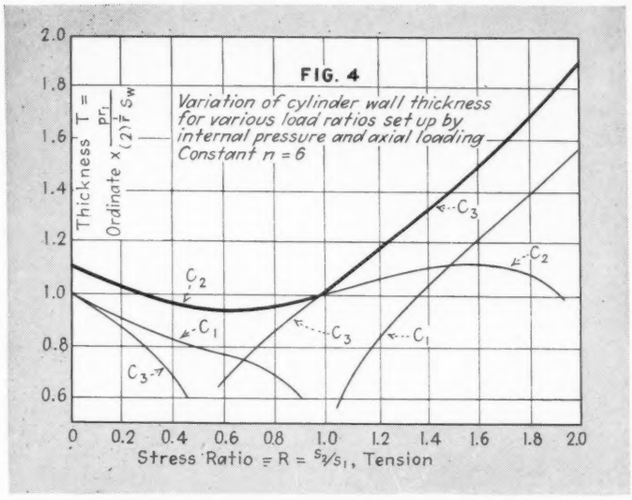


FIG. 4
Variation of cylinder wall thickness for various load ratios set up by internal pressure and axial loading Constant n = 6
Thickness T = Ordinate x pr/(2)^(1/n) Sw
C1
C2
C3
Stress Ratio = R = S2/S1, Tension

Fig. 4—Relations between thickness of tube wall (subjected to internal pressure and axial loading) and working stresses where radial stress is negligible

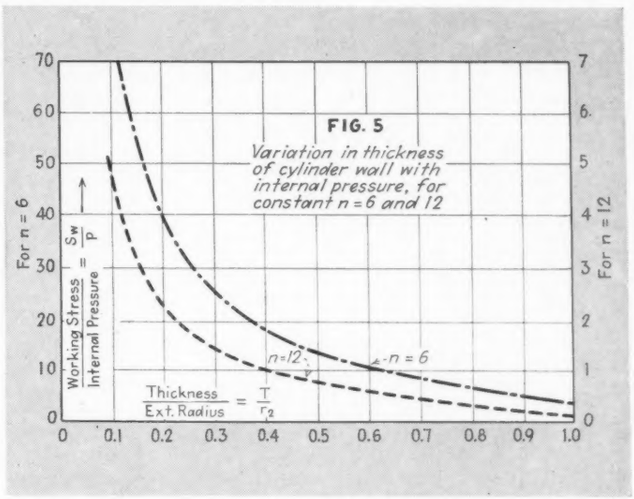


FIG. 5
Variation in thickness of cylinder wall with internal pressure, for constant n = 6 and 12
For n = 6
For n = 12
Working Stress / Internal Pressure = Sw/p
Thickness / Ext. Radius = T/r2
n=12
n=6

Fig. 5—Variations in thickness of thick-walled cylinder subjected to internal pressure where radial stress is not negligible

for simple tension S_w divided by a quantity which is a function of the ratio S_2/S_1 of the principal stresses.

Equation (5a) only considers the creep rate C_1. It may be that the creep values in the other two directions are the critical ones. Equating these creep values to the allowable value in tension the working stress values for S_1 are for C_2 and C_3 respectively:

$$S_1 = \frac{S_w}{\sqrt[n]{\frac{1}{2}(1-R+R^2)^{\frac{n-1}{2}}(2R+1)}} \qquad (5b)$$

and

$$S_1 = \frac{S_w}{\sqrt[n]{\frac{1}{2}(1-R+R^2)^{\frac{n-1}{2}}(R+1)}}$$

The governing value of S_1 for a predetermined stress ratio R is the maximum value in Equations (5). This is best determined by plotting the relation between R and S_1 as shown in Fig. 2 for a value of $n = 6$, a value recommended by Bailey for medium carbon steels. From this diagram it is shown that the creep C_1 is the critical one for values of the stress ratio R from $+0.5$ to -1.0, and that for values of R from $+0.5$ to $+1.0$ the creep C_3 governs. Fig. 3 gives the final working stress values S_1 for varying stress ratios $R = S_2/S_1$ and for various values of n. This shows that a variation of n makes comparatively little difference in the working stress values where the principal stresses are of opposite signs. It is now of interest to apply the above to the design of members.

Applications

Thin-Walled Cylinder Subjected to Internal Pressure and Axial Loading— For applications where there exists thin-walled cylinders subjected to internal pressure and axial loading accompanied by creep due to high temperatures, such as steam piping and tubes of various kinds, consider that the internal radius of the cylinder $= r_1$, external radius $= r_2$ and the thickness $= T$. If the internal pressure is p and the axial load is F, the principal stresses S_1 in the circumferential direction and S_2 in the axial directions are

$$S_1 = \frac{pr}{T}, \text{ and } S_2 = S' + \frac{S_1}{2} = R\,S_1 \qquad (E)$$

where S' = the stress due to the axial load $F = \frac{F}{2\pi r_1 T}$

and $R = \frac{S_2}{S_1} = \left(\frac{F}{2\pi r_1^2 p} + \frac{1}{2}\right)$ (F)

The stress S_3 in the radial direction can be assumed equal to zero for thin-walled tubes. Considering the creep C_1, Equation (D) defines the relation between the stresses S_1 and S_2. Thus placing values of S_1 and S_2 from Equation (E) in Equation (D) the thickness of tube required for a working stress S_w is

$$T = B\left[(R^2-R+1)^{\frac{n-1}{2}}(2-R)\right]^{\frac{1}{n}} \qquad (6a)$$

where $B = \frac{pr_1}{S_w^{\frac{1}{n}}}$ and R is defined by Equation (F).

In the same way for the creep values C_2 and C_3 the required thickness T is

$$T = B\left[(R^2-R+1)^{\frac{n-1}{2}}(2R-1)\right]^{\frac{1}{n}} \qquad (6b)$$

and

$$T = B\left[(R^2-R+1)^{\frac{n-1}{2}}(1+R)\right]^{\frac{1}{n}} \qquad (6c)$$

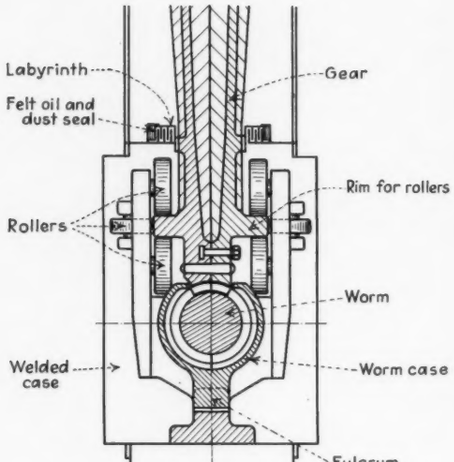
The governing value of the thickness T in Equations (6) depends on the load ratio R. Fig. 4 shows the variation of the thickness T for various load ratios R, using a value of $n = 6$ recommended by Bailey for medium carbon steels.

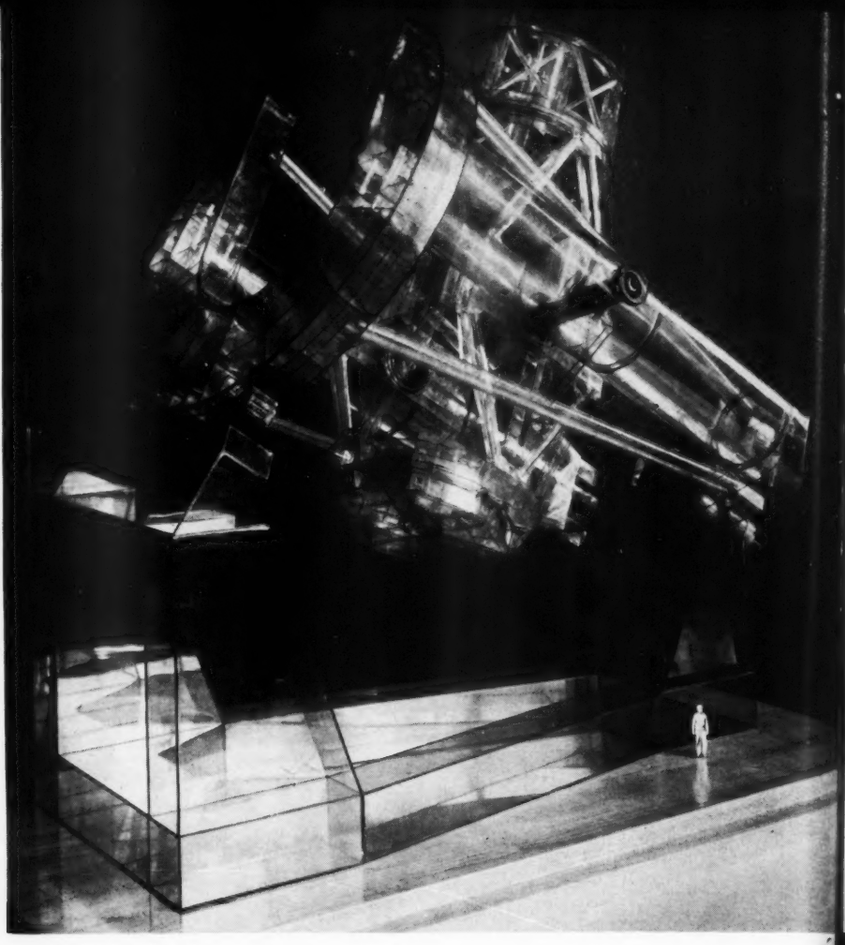
Thin-Walled Cylinder Subjected to Internal Pressure and Pure Bending— For applications in which tubes are simultaneously subjected to internal pressure p and a bending moment M. Such loading produces an axial stress S_2 and a circumferential stress S_1. For a thin-walled cylinder the radial stress S_3 can be assumed equal to zero. The creep rate values are then the same as in the previous example; if for the axial stress S_2 is substituted the corresponding stress $\left(\frac{S_1}{2} + S_b\right)$ where $\frac{S_2}{2}$ is the axial stress caused by internal pressure p and S_b is the stress due to the moment M. Then placing $S_2 = RS_1 = \left(\frac{S_1}{2} + S_b\right)$ the values of the thickness required is defined by Equations (6). Fig. 4 shows the variation in the thickness.

Thick-Walled Cylinder Subjected to Internal Pressure. For cylinders subjected to high pressures it is necessary that the thickness be large in order to resist the load, and the stresses determined for a thin-walled cylinder cannot be used, since the stress S_1 is no longer uniform throughout the wall and the radial stress S_3 is not negligible. An analysis made by the writer, using the Soderberg theory in the three-dimensional form shows that the thickness required for a pressure p is defined by

$$\frac{S_w}{p} = \frac{1}{n}\left(\frac{3^{\frac{n+1}{2}}}{2}\right)^{\frac{1}{n}}\left[\frac{1}{1-\left(1-\frac{T}{r_2}\right)^{\frac{2}{n}}}\right] \qquad (7)$$

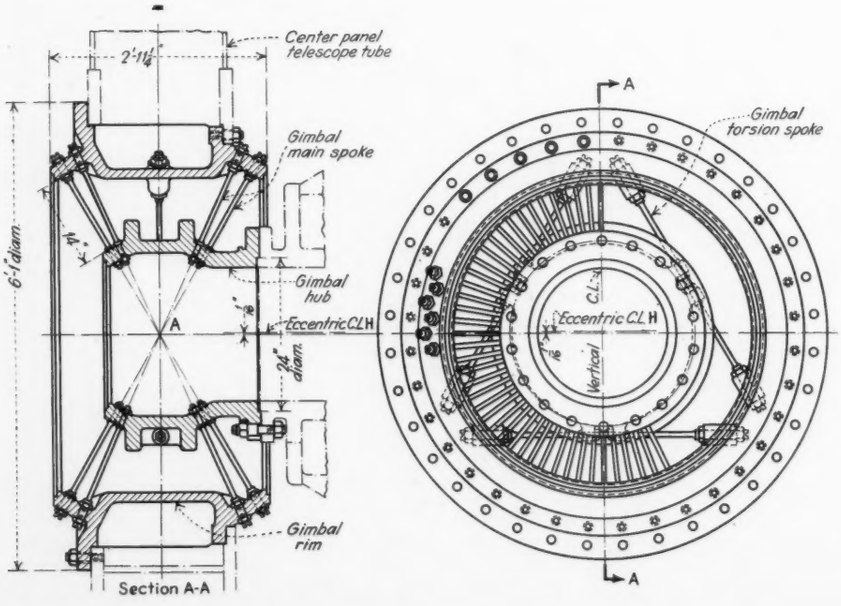
The variation in thickness T with pressure p for values of $n = 6$ and $n = 12$ is shown in Fig. 5 in graphical form.





MODERN MECHANICAL DESIGNS

200-Inch Telescope Mounting in Construction at Westinghouse Electric & Manufacturing Company



EACH section of the tube and mount is a welded structure with mechanical bolted joints for assembling. Hot rolled low carbon steel plates and structural shapes are used throughout. After welding each section was annealed to relieve internal stresses.

Several sub-assemblies bolted together form the tube—22 ft. diam. by 45 ft. long weighing 75 tons—the cage, top ring, five central panels, a bottom ring and a mirror cell. These will be lined up in the shop and shipped in one piece.

The yoke is composed of ten major sections. The horseshoe on its north end is 46 ft. O.D., 4 ft. thick, with a throat opening of 24 ft. and with balancing pieces will weigh 200 tons. This will be the world's largest bearing journal and will be supported by oil pad type bearings consisting of two pads 28 in. by 28 in. on each side of the vertical centerline. Each pad will carry about 150,000 lb. and is mounted on a hardened ball and seat so as to adjust itself to the horseshoe surface. The two pads on each side are balanced against each other by an equalizing member having a hardened roller and seat. Oil film is maintained by feeding oil into pad recesses at about 300 lb. per sq.in. pressure. The only frictional forces to be met are the shearing forces created in the oil film.

The third point of support is at the south bearing which is a large spherical bearing and will carry about 580,000 lb.

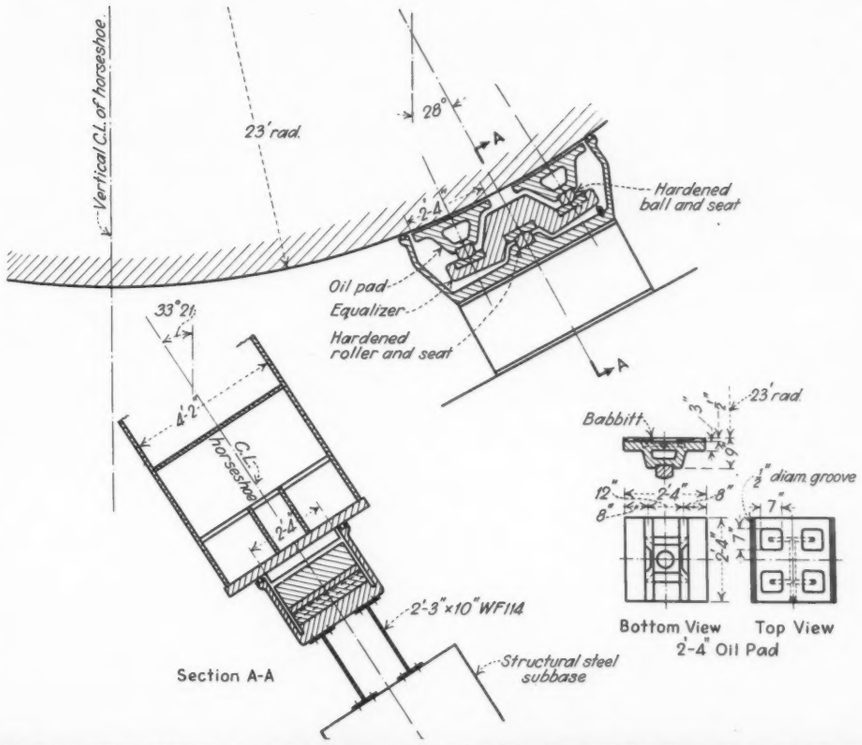
thrust load and 350,000 lb. lateral load. Estimated torque to rotate whole mount is 50 foot pounds.

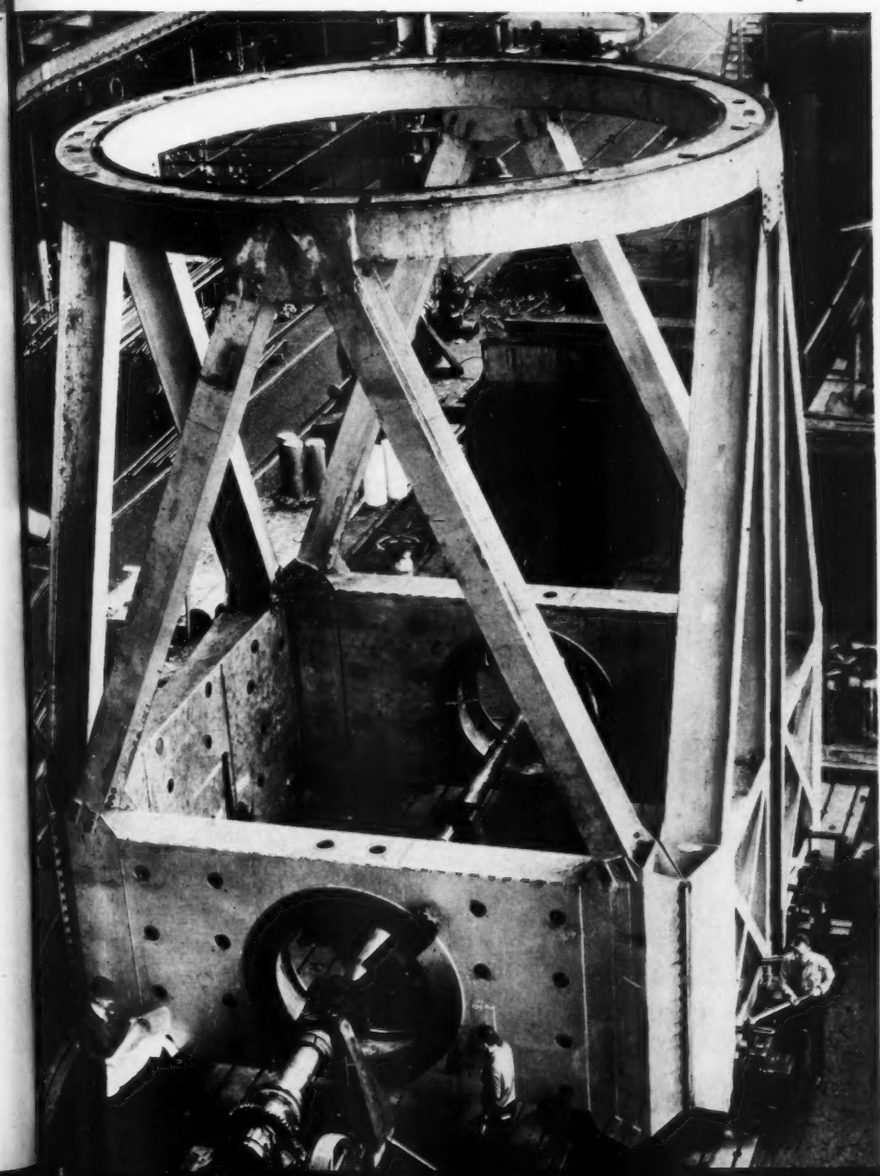
Distortion of tube at connection to yoke is eliminated by using a flexible gimbal to maintain point support with bending moments in elastic spokes so small that they are negligible.

Flexible corners on center box of tube design make all deflections of tube statically determinate. These "elastic hinges" give little resistance to bending but great resistance to stretching.

Power necessary to move the tube is applied through a "floating worm" which is guided by a device supported through rollers by the rim of the worm wheel; this arrangement compensates for the relative deflection between the tube and yoke.

Engineering operations involved building models of translucent plastic material to $\frac{3}{32}$ scale to check theoretical calculations. To avoid squeezing the model the micrometers used in tests were tied into an electrical circuit with meters to indicate when point contact was made.





EXTRUDED ZINC PARTS

Produced by Impact Method

HERBERT CHASE

Recently developed process makes possible economical quantity production of designs having wide range of shapes and sizes and marked variations in section thicknesses, with integral projecting lugs, bosses and tubular extensions

BETWEEN certain classes of products produced by the conventional drawing processes employing sheet metals and those fabricated by forging, there is a group of intermediate products made by impact extrusion. Although they sometimes duplicate parts made by drawing, they are more generally parts that include variations in section thickness and often have projecting lugs which cannot be incorporated as integral parts of drawn products. Unlike most forgings, parts produced by impact extrusion are the result of a single impact, and the section thicknesses may be much less and the dimensions much closer than are attainable by forging. A few of the parts produced by impact extrusion can be approximated, as to shape and dimensions, by die casting, but only in metal having the characteristics of a casting as contrasted with a wrought metal, so that in practice there is little competition between these two methods.

Zinc Now Used

Impact extrusion involves the use of a punch and die in a heavy press of special design. Under the impact of the punch, solid metal in the shape of a circular slug is caused to flow and assume the form desired. Obviously, a highly ductile metal, such as aluminum, zinc, tin or lead, must be used. Extrusion of aluminum (See *Product Engineering*, April, 1934) has been done commercially for many years by a number of companies. Extruded zinc parts, although a comparatively recent development, are now being produced in large quantities.

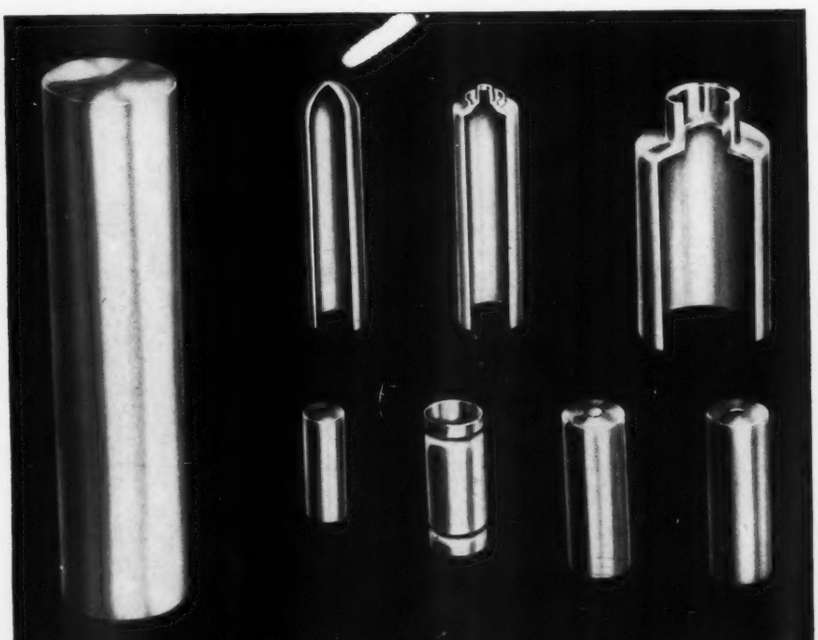
Under normal conditions of the metal market, the commercial grade of zinc used for extruded parts is somewhat lower in cost than aluminum. It has the advantage of being easily soldered, which is of special importance in electrical and certain other applications, and of being less resonant, a property of considerable significance in the making of auto-radio vibrator cases in which quietness of operation is important. In most other respects, the properties of the zinc used are similar to those of aluminum except that the zinc tarnishes more quickly. Zinc is, of course, much superior in physical properties to tin and lead, which are extruded chiefly to form containers for tooth and similar pastes, where soft metals are suitable.

Among the important applications of extruded zinc parts are electric condenser "cans," coil shields, flash-light cases, inclosures for various radio devices including the vibrator unit previously mentioned and certain accessories intended for use as noise filters and aerial eliminators. In addition, some products of this process have been used for packaging metal parts.

Extruded zinc applications are usually confined to cylindrical parts with or without solid lugs or tubular extensions on the bottom. It is entirely feasible, however, to produce circular flanges with hubs or other extensions and with or without tubular extensions. Thus small gear blanks or pulleys can be made with web and hub and, unlike stamped or drawn parts, with marked variations in section thickness.

The Process

The process of extrusion, which in some cases closely resembles forging but it is done with a single blow, work-hardens the metal and renders it stiffer for a given section thickness than the metal in the slug. The diameter and thickness of the slug used varies with the part to be produced and has the same volume except for a slight allowance for trim. Slugs have to be slightly smaller in diameter than the die open-



A few of the numerous parts produced in large quantities by impact extrusion of zinc, showing the range of sizes and variations of section thicknesses attainable

ing, which controls the diameter of the piece, and the thickness of a slug never excedes and is usually much less than its diameter. Conversion of the slug to the form of the part produced results from the impact of the punch, which is smaller in diameter than the die opening by an amount equal to twice the tubular wall thickness of the part. The impact pressure of the punch upon the ductile metal causes the slug to expand, fill the die, and then flow upward around the punch through the annular space between the punch and the die cavity.

Metal extruded upward through the annulus forms the side wall of tubular parts, and that remaining between the die and the punch, when the latter is at the bottom of its stroke, forms the bottom of the part together with any projections on that portion of the piece. When the punch is withdrawn, the extruded part is stripped from it. Since the part is formed in a single stroke, the time required is short and production is correspondingly rapid.

If a hole is required in the center of the bottom, a slug with a central hole is sometimes used. The hole can also be punched in a separate operation and it can then be located in any part of the bottom, or more than one hole can be punched if desired.

Integral Projections

As compared to drawn parts, which when deep usually require two or more drawing operations with a corresponding increase in die costs, the process is faster and involves less handling. In addition, the bottoms of the parts can be of almost any thickness or of a varying thickness and can have integral projections, either solid or hollow. Such projections need not be coaxial with the punch but can be offset, and more than one can be provided on each part if required. Offset lugs should not be placed close to the edge of the bottom but sometimes can be offset a distance equal to as much as half the radius of the bottom. Although a symmetrical distribution of the metal about the punch axis is desirable, it is not essential.

Sizes and Tolerances

The punch and die may have flat bottoms, but slightly conical bottoms are desirable since they have a tendency to hold the punch concentric with the die and thus make for uniformity in wall thickness. Wall thicknesses are readily held within plus or minus 0.003 in. of nominal thickness, sometimes closer, and bottom thickness within plus or minus 0.007 in. for commercial tolerance.

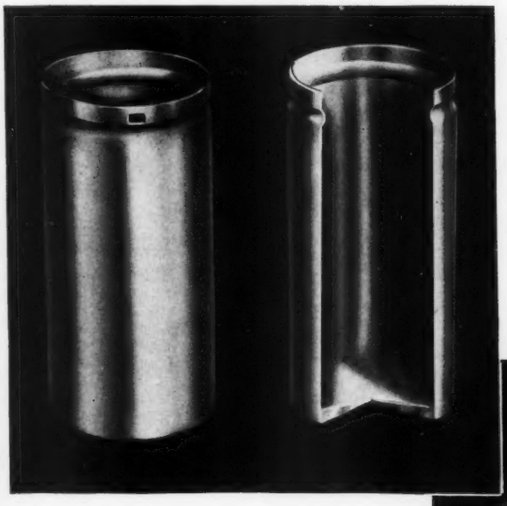
Outside diameters of extruded zinc products thus far produced have ranged from 0.437 to 2.125 in. Within this range a number of diameters have been standardized and, when adhered to by designers, permit new parts to be made with minimum tooling costs, since existing dies may be employed for the extrusion as well as for punching the slug. Wall thicknesses can be varied within certain limits, the lower limit being about 0.020 in. for the largest size and about 0.014 in. for the smaller sizes, although some parts with a minimum wall thickness of 0.012 in. have been made. Total height of side walls ranges from 2½ in. maximum for the smallest, up to 7 or 8 in. for the largest diameter. Maximum wall thickness depends on the volume of slug, thickness of bottom, and total height required.

Subsequent to the initial forming, any one or a combination of supplementary operations can be performed readily on extruded parts. Holes can be punched in side walls or bottoms. Lugs can be threaded, tapped, or riveted over as, for example, in fastening a supporting bracket to the piece. Side walls can be given a rolled bead. The latter is frequently done at the top of cans or cases. A sealing disk is then pressed in against the top edge of the bead and the metal above the disk is rolled or spun over to seal the case and its contents. Even after the work-hardening produced by extrusion, the zinc is amply ductile for such operations.

Highly important in respect to utility is the smoothness of finish obtainable in extruded zinc parts and the fact that they are non-rusting and capable of taking applied finishes. Such finishing not only contributes to protection of the metal surfaces but also can be highly decorative and thus have much to do with the sales appeal of the product. Some finishes can be applied, as on tubes for pastes, by an offset printing process with great rapidity. Many color combinations are obtainable as well as an infinite variety of designs, such as those required in trade marks and labels and including, of course, whatever lettering and the like that may be needed.

When an applied finish is not required, identifying marks or brandings are readily applied by rolling or other embossing dies. Should a bright metal finish be desired, plating with nickel or other metals is entirely feasible after proper buffing and cleaning. Enduring organic finishes are also applicable.

Many hundreds of thousands of certain extruded zinc parts have already been produced and there is little doubt that the process will be applied to a wide range of other parts once its possibilities become more generally known.

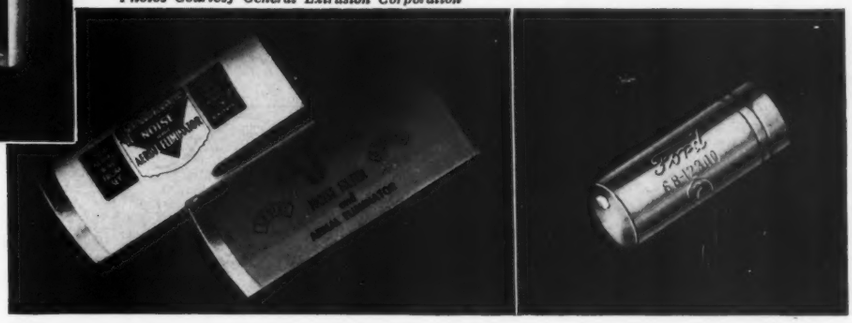


Case for auto-radio vibrator unit, made of extruded zinc to minimize resonance

Finishes in a variety of color combinations and designs can be applied to extruded zinc parts by offset printing process

As on this condenser case for the Ford car, an offset lug can be readily provided on the bottom of zinc parts made by impact extrusion

Photos Courtesy General Extrusion Corporation



Westinghouse Photo

DESIGNING SAND CASTINGS

for Best Foundry Results

Incorporating features in design which allow for the behavior of cast metals and facilitate foundry processes, assists materially in producing castings that are sound and of high quality

SO GREAT and rapid have been the advances in foundry technique over the past decade that many designers are not fully aware of the extent of the results achieved. Factors formerly left to the individual molder's prejudices or guesses are now determined in progressive foundries by scientific control methods. Thus, to check and to determine the variables which occur in molding sand, testing apparatus and equipment is used for accurately measuring permeability to gases, moisture content, density or compactness, and resistance to impact and shear.

Furthermore, by laboratory observations of metallurgists and research engineers, foundries have reached a high degree of quality control. As a result of this progress, designers can now procure castings having physical properties which are considerably better and of much more uniform quality, than those which were obtainable a decade ago.

But a casting cannot be made to possess high qualities if its design does not conform to the requirements of good foundry practice. That is why foundrymen are urging designers to recognize their responsibilities in the production of good castings. When designing a casting, a study of the manual and mechanical operations that will be involved in casting the part will suggest features that can often be incorporated in the design to facilitate the casting operations. For this reason, the designers that cooperate with the foun-

drymen make it possible for the foundry to deliver strong and sound castings of high quality, and such designers are using castings more frequently and to good advantage.

Naturally sand castings will not meet all the physical, chemical and operating requirements for every kind of service. But their field of use is now much broader than is commonly supposed. The inherent advantages in this type of construction make their use highly desirable for many applications. Design simplicity is achieved not only because castings can be made in the form and size best suited but also because constructional details such as pads for areas that are to be machined, ribs for reinforcing heavily loaded sections, brackets and flanges for connections with other parts, lugs for various purposes and associated parts can usually be incorporated in the casting to make a compact unit without mechanical joints. And for any application, sand castings can be had in a variety of materials offering a wide range of physical, chemical and fabricating qualities.

Foundry Suggestions

Since the design of the part dictates the form of the pattern, and in turn the pattern dictates the casting method, it follows that the proper time for the machine designer to consult the foundry is when the design of the casting is still on the drawing board. The foundryman can then plan and discuss how he will handle the piece and make many valuable suggestions towards the securing of best results.

The foundryman will want to decide with the designer on the location and size of gates and heads to suit the position of the mold when the molten metal is poured, to promote convenience in casting, and to secure adequate feeding of all the members of the casting to assure soundness.

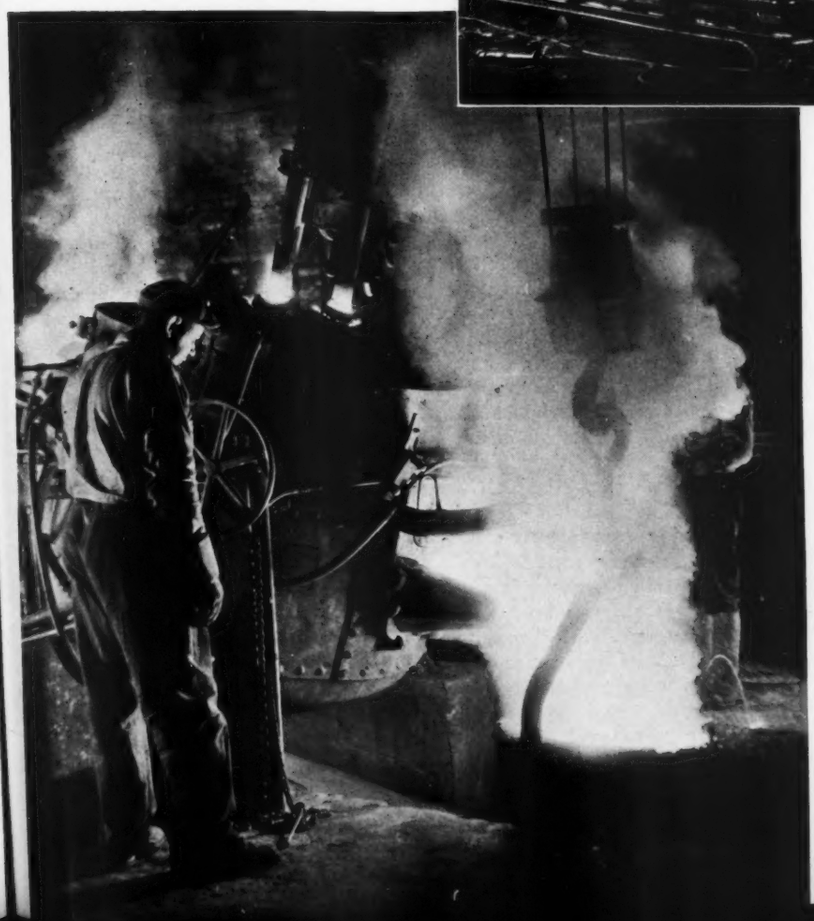
To obtain a casting that will satisfy dimensional requirements, the designer can check with the foundry the amount that the casting will contract or shrink in the mold when cooling from the freezing temperature of the metal, since this factor varies with the casting design, type of metal, pouring temperature and the resistance of the mold to normal contraction of the casting.

When possible it is best to arrange the design so that all surfaces that are to be machined will be cast in the drag side. Because experience has shown that this portion of the casting will be less likely to contain slag and blow holes should any be present. Sometimes it is necessary to allow more metal for finish if the surfaces that are to be machined are cast in the cope.

Pattern Details

Deep pockets, undercut cavities and recesses that make drawing the pattern or lifting the cope difficult are well known sources of trouble in the foundry. It is hardly necessary to observe that the design should be such that after ramming it will be possible to readily withdraw the pattern from the mold without breaking the walls of the cavities by pattern parts that will not draw easily. Also, the shape of the pattern should be such that the molder has sufficient space for the operation of ramming.

American Foundry Association



The taper or draft provided on all withdrawing faces of patterns to facilitate withdrawal from the mold is an important detail that must be considered in all casting design. If draft reduces a section enough to make it smaller than that needed to support its working load or otherwise impair the use of the casting, the working-drawing should specify whether the draft is to be added to or be subtracted from the dimensions as given.

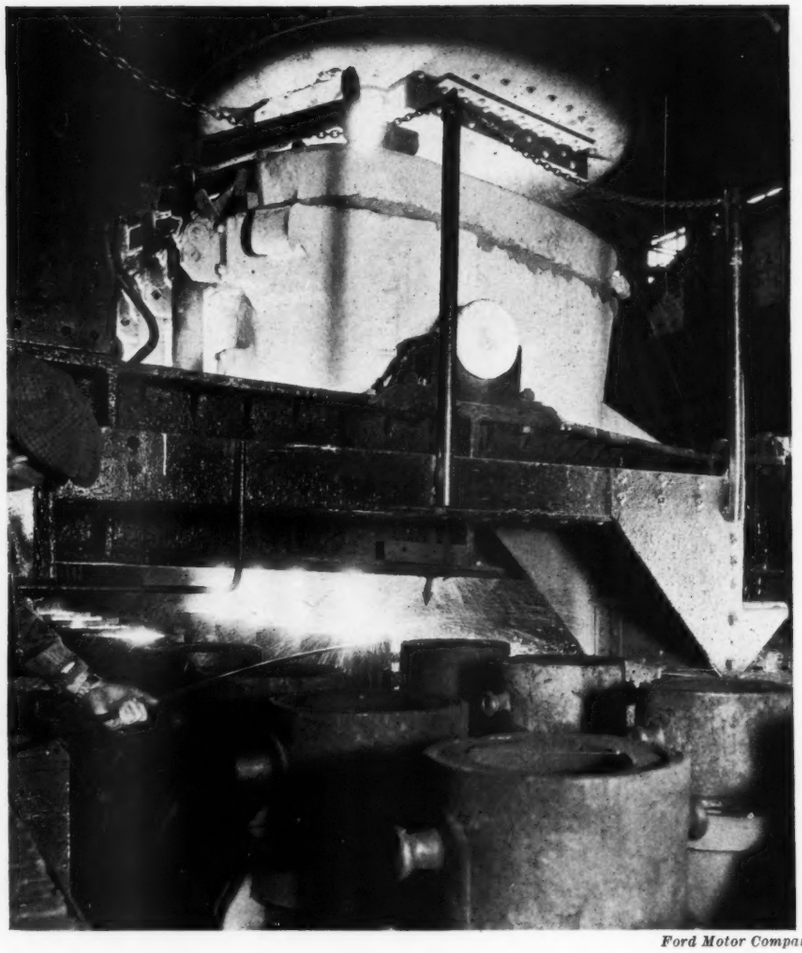
While for hand molding the amount of draft is usually not less than $\frac{1}{16}$ in. per ft. in the direction of withdraw-

ing, it is often increased or decreased. depending upon the shape and size of the casting and whether molded by hand or by machine.

Sometimes reference points on the casting are of value in the machine shop to make layout work easier. If wanted they should be indicated on the drawing so that the casting can be checked always from the same point of origin by the pattern shop, foundry and machine shop. To insure the most accurate results the points should be as far apart as possible and should be placed on the same side of the parting line so that they will not be influenced by the shifting of a core, the cope or the drag.

Obviously on the basis of economy of material a well designed casting is one with sections no thicker than are essential to secure the desired strength, yet on the other hand, to obtain quality the sections must be proportioned to avoid local slow cooling, and the minimum section thickness for the various cast metals must be carefully observed. Soft gray cast iron can be poured into sections as thin as $\frac{1}{8}$ in. and retain its grayness. White iron if poured into heavy sections may become gray, while gray iron may become white at the corners and edges if poured into very thin sections.

Designers have found that in some special applications steel castings can be poured with wall thicknesses as small as $\frac{1}{8}$ and $\frac{3}{16}$ in., depending on the design of the casting. However, $\frac{1}{4}$ in. is the generally accepted minimum wall thickness for steel castings.



Ford Motor Company

Minimum Metal Thickness

Although malleable iron is commonly cast in sections $\frac{1}{8}$ in. thick, it is better if the average minimum casting section is approximately $\frac{1}{4}$ in. thick. Malleable iron makes satisfactory castings up to several inches in thickness, depending on other dimensions and the design of the parts. Castings of this material are made in weights varying from a fraction of an ounce to more than 1,000 lb., although the greatest production of malleable iron is in castings less than 25 lb. in weight.

The minimum section thickness for non-ferrous castings varies with the alloy, size and intricacy of the casting. Castings poured at high temperatures to run extremely thin sections generally do not have the best physical characteristics. With brass and bronze the minimum satisfactory metal section is considered to be about $\frac{3}{32}$ in. With aluminum alloys $\frac{1}{8}$ in. sections have been cast satisfactorily, although a minimum thickness of $\frac{3}{16}$ in. is preferable.

In general, section thicknesses are proportioned to the areas or diameters to be run or fed through them and designers can help the foundry produce good castings by maintaining uniformity in section thickness. From a foundry standpoint, this is very desirable, because of the equalized rate of solidification, simplified gating and feeding, and the reduced tendency to set up internal strains, shrinkage defects and cracks. The old rule that inequalities in thickness of adjoining sections and members are to be avoided because they tend to retard progressive solidification or feeding of lighter to heavier sections is still good practice. Thin and small sections cool and freeze quickly and if heavy sections are fed through them, there is danger of metal freezing in the thin part and shutting off the subsequent feeding of liquid flow of metal from thick overlying members to compensate for the contraction that follows the filling of the mold cavity.

For the same reason, metal sections connecting projecting pads, brackets and lugs to the body of the casting are made uniform in area to permit adequate feeding from the main section.

Since sharp corners and reentrant angles are a source of cracks and sand washes, they also are avoided by the designer. Therefore, corners are well rounded and fillets are used at all intersections, with fillet dimensions depending upon the shape and size of the casting.

Occasionally ribs are wisely incorporated in the design to strengthen the casting to resist service loads. More often ribs are provided to reinforce the casting against cracking strains during solidification. This practice is evident in many designs where the construction of the mold is such that the sand mass prevents the casting from normally shrinking. Much of the buckling and bulging of large flat areas when cooling after solidifying can be prevented by ribs properly proportioned and located.

Cores and Mold Size

Some designs call for the use of external cores on which core prints are provided as anchors to prevent shifting to an incorrect position. Core prints not only serve as anchors, they also are used to support the weight of the core to prevent sagging.

Since the cost per mold increases with its size, the time spent when de-

signing in considering the size of the mold necessary to make the casting often cuts down foundry production time. It is occasionally found that the total mold bulk is advantageously reduced by making the part as two or more castings, or by redesigning the part to take a smaller flask.

Casting Metals and Alloys

It is common practice to knurl, groove or notch metal inserts such as studs, eye bolts, bar handles and other parts which are to be cast in, to obtain a firm attachment, and to proportion the metal skilfully around the insert to resist cracking when the molten metal becomes solid and shrinks.

In the selection of a metal or an alloy for a casting for any particular application, the designing engineer has many to choose from. His choice is influenced by individual characteristics such as strength, toughness, hardness, density, corrosion resistance, heat resistance, shrinkage, melting point, color, polishing qualities, and other properties. Often the requirements demand a number of such qualities in the same casting and a compromise is necessary. Alloys requiring special manipulation and special equipment should not be selected unless the foundryman is made familiar with the problems involved and is prepared to do the work.

Steel castings are generally used for parts where high strength and ductility are required, since they can be produced in forms and shapes not possible to make by forging operations. Here, too, good design dictates that sections be uniform, and that where both heavy and light sections are used provision be made for feeding while cooling to avoid resultant shrinkage cracks. Castings with irregular sections are not made as easily in steel as in iron, because steel shrinks more than does iron when solidifying within the mold.

Alloy-steel castings, obtainable in a great number of varieties, are now used for numerous industrial purposes; their greater strength and other properties justify their use where light weight and high stress resistance are desirable. Because stainless-steel castings are relatively difficult to cast and because their shrinkage is high, their design should be made as simple as possible. Alloy-steel castings, in common with wrought alloy steel parts, are specially heat-treated to develop their best physical characteristics.

Gray Irons

Because iron can be cast into almost any design, and its many important properties cover such a wide range, it has for centuries been used for many general purposes in structures and the building of machinery. Its resistance to wear, to heat and to corrosion make cast iron desirable for many applications. The high vibration dampening capacity of gray iron has been found to vary with the plastic deformation, so that the stiffer the iron the lower is its damping capacity. High total carbon, high graphite irons of relatively low modulus of elasticity usually have higher damping capacity than steels and carbon irons. Gray irons have much higher damping capacity than steels and because of this, gray irons are preferred in certain castings used on machinery where vibration is a factor. Cast gray iron is popular also because of its excellent machinability.

Westinghouse Photo

Unalloyed gray irons are used for some parts subjected to moderately high temperatures; at very high temperatures growth occurs because of graphitization of the cementite in the pearlite, and also because the products of corrosion of the metal occupy a greater volume than the original metal. When the iron casting is exposed to very high temperatures a good design makes allowances for the transformations that occur.

To resist severe abrasion, in many types of service white cast irons are preferred, with a Brinell or other hardness values specified which are generally believed to have some relationship to abrasion resistance.

The development of the alloyed gray irons during the past few years, along with the higher alloy white irons has enabled the designer to use a series of low-cost corrosion resisting metals. The properties of these new alloys have contributed much to the increasing use of cast irons.

Bronzes

Numerous types of bronze alloys have been developed for the use of the designer, with properties and characteristic qualities as determined by the elements that are alloyed with the copper. Some are hard and brittle, others are soft and tough. The aluminum bronzes when heat-treated have many desirable properties. The tin and lead groups of bronzes are still rated high for bearing materials.

Since bronze can be fabricated easily and is resistant to atmospheric corrosion, it is sometimes used because of its color to secure good appearance and attractiveness, even though the cost of the material is somewhat high.

Because bronzes, as a class, when molten oxidize easily, the foundry takes special precautions to prevent oxidation that might impair the physical properties. The temperature of pouring also influences the strength and ductility of many bronze compositions.

Aluminum when alloyed with copper, magnesium and other elements has many well-known desirable physical characteristics. Like the bronzes, many of the aluminum alloys are soft and tough while others are strong but brittle, and some will develop strength and ductility when heat-treated. The high conducting properties of aluminum present an advantage for some applications where electric current is involved.

There is now much data available as a guide in the selection of casting materials best suited for a given application. Records of laboratory tests and performance trials have been collected and arranged for quick reference and use by designers.

PERMANENT MAGNETS—III

How They Are Being Applied

J. DELMONTE

Versatility and suitability of permanent-magnet applications are emphasized by the variety of examples, both typical and unusual, that are presented in this discussion, completing the series

THE indispensibility of permanent magnets to magnetos, telephones, and instruments has long been unquestioned. For such applications, the designer is accustomed to think in terms of permanent magnets rather than electromagnets and incorporation of the former in such devices is taken almost as a foregone conclusion. In other fields, however, there are many places where the possibility of using permanent magnets, particularly the new aluminum-nickel-alloy types, is not accorded the consideration that they deserve in view of their improved characteristics. Nevertheless, applications of permanent magnets are rapidly expanding and their use in the future will undoubtedly be much more common and accepted than is now the case.

In general, as was pointed out in Part I of this article, permanent-magnet applications can be divided into three major classifications: (1) applications requiring a constant magnetic field; (2) applications utilizing stored magnetic energy; and (3) applications combining electromagnets and permanent magnets. These classifications relate primarily to electrical uses, an example of the first group being a moving coil ammeter, of the second a magneto, and of the third a telephone receiver. In addition, permanent magnets are applicable to a wide variety of mechanical uses, and these applications may be considered as secondary groups or subdivisions of either the first or the third classifications, examples of each being respectively a magnetic chuck and a magnetically held-in contactor which will be described later.

For certain applications there is some question as to the relative merits of electromagnets and permanent magnets. It is necessary to decide between these two types of magnets, for example, in designing a vibration pickup unit, a device of value in ascertaining the vibration characteristics of domestic appliances, automotive equipment, and industrial machinery. The writer has observed that an appreciable saving in the weight of the device can be realized by the use of a permanent magnet to supply the field flux. In addition the wiring circuit is simplified by the elimination of the leads and power supply for the field coils required by the electromagnetic type of device. The new aluminum-nickel-alloy permanent magnets, being particularly resistant to shocks administered by vibrating equipment, are fully capable of meeting the requirements of the application.

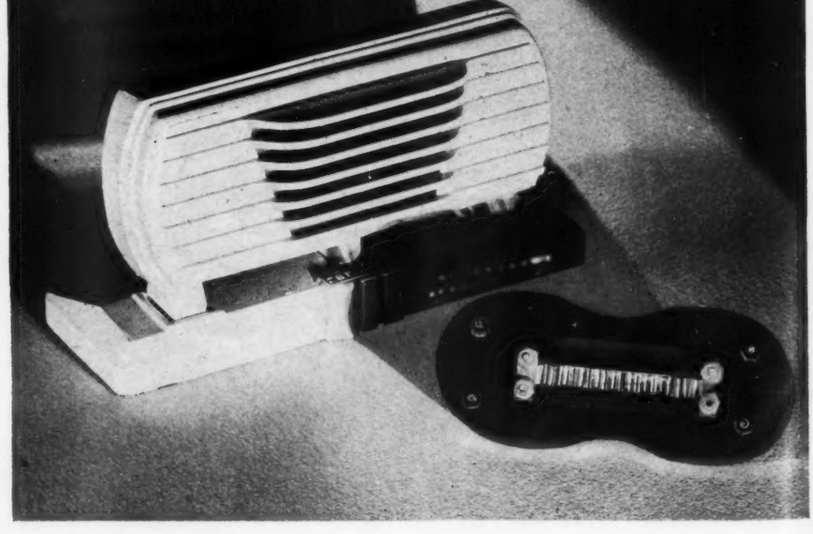
Permanent magnets are being used in a wide variety of instrument applications. As the rotors of small a.c. generators, for example, they are being employed in tachometer designs. The generators are connected to the equipment, the speed of which is to be determined, and their output may be applied either to a moving-coil instrument which gives the indication directly or to a small synchronous motor driving a magnetic-drag tachometer, which, of course, also utilizes a permanent magnet. With the latter arrangement, used frequently in aircraft tachometers, the speed indication is unusually independent of temperature effects since the generator frequency is the sole factor determining the speed of the synchronous motor. The only possibility, therefore, of temperature errors is in the magnetic-drag tachometer. This consists essentially of a permanent-magnet rotor, an inductor drum mounted so that it can rotate about the rotor, and a calibrating spring for the drum. The rotating field of the rotor generates an electric current in the drum, causing a torque against the calibrating spring. As a result, the drum rotates until its torque balances that of the spring and thus gives the desired indication. A temperature compensating means can be incorporated in the instrument to eliminate almost completely any trace of temperature error.

From the above, however, it should not be inferred that temperature errors in aircraft tachometers are always of major consequence since, in the light of other errors, they may be of little concern. Nevertheless, this method of avoiding them should be of interest.

Of a different nature but still within the first classification is the use made of a small permanent magnet in a compact d.c. starting switch for fractional-

Two simple aluminum-nickel-alloy castings and a thin, corrugated aluminum-alloy ribbon constitute the essentials of this recently developed velocity-type orator's microphone

Courtesy Indiana Steel Products Co.



horsepower motors. The magnet, of nickel-aluminum alloy, is mounted near the switch contacts to provide a blowout action that assists in interrupting the arcs drawn when the circuit is opened and thus contributes to high interrupting capacity and long contact life.

Among the more recently developed devices illustrating permanent-magnet applications of the second classification is a so-called velocity-type microphone for radio and public address use. In this, two identical aluminum-nickel-alloy castings are so designed that they can be readily ground to finished dimensions and assembled together in such a way as to permit accurate location of a very thin, corrugated aluminum alloy ribbon in the air gap between them. Vibration of the ribbon in the field generates the voltage applied to the amplifier.

Thumb lever on this hand magnet operates shunt releasing work

Applications of the third classification, combining electro magnets and permanent magnets, are exemplified by telephone receivers and certain radio loudspeakers and by the magnetically held-in contactor previously mentioned. This device embodies a held-in construction whereby the solenoid coil is energized only momentarily when the contactor is being opened or closed. It is similar in construction to standard contactors, but an aluminum-nickel-alloy permanent magnet, a copper-oxide rectifier and the necessary electric interlocks are also included. The start button picks up the coil by energizing it through the rectifier in one direction. An interlock then breaks the coil circuit and the armature is held in the closed position by the permanent magnet. The stop button energizes the coil through the rectifier in the opposite direction, thus forcing the armature out to the open position where another interlock opens the coil circuit. The device therefore eliminates holding current, making operation economical where the contactor remains closed over long periods. Undoubtedly many other opportunities exist for the application of permanent magnets, in place of holding coils or mechanical latching arrangements, to magnetic switches, relays and similar electric control devices.

Mechanical Uses

The field of mechanical uses opened by the development of the newer permanent-magnet materials is broad. One example is an electric switch, the snap action of which is effected by a permanent magnet instead of the usual spring arrangement. As soon as the switch armature is pushed past the dead center between the poles, it is snapped against the nearest pole and held there by magnetic attraction. In an aircraft-engine manifold-pressure gage, the mechanism is housed entirely within a vacuum-sealed brass cartridge. Instead of piercing the cartridge to bring out a shaft for the indicating pointer, a permanent magnet on the inside of the housing revolves and causes the pointer on the outside to follow its motion exactly, thereby registering the desired indication. Undoubtedly this arrangement can be applied to many devices operating in dusty atmospheres or explosive gases, since the permanent magnet can be used not only to transfer a circular motion through the housing, but also to effect straight-line motion in one direction through attraction or in two directions, using two magnets, through attraction and repulsion obtained by reversing poles.

Hazardous gases, too, constitute the chief reason for another mechanical use of permanent magnets. In a materials-handling setup for light-gauge steel strip it was found necessary to hold the strip to a conveyor roller by magnetic attraction. Because of the presence of lacquer fumes and the danger of sparks from the open slip-rings used on rotating electromagnets, a conveyor roller incorporating four large cylindrical permanent magnets was employed. Although relatively expensive in first cost, it eliminates the sparking hazard and consumes no electric current during operation. Similar permanent-magnet conveyor rollers could be used in conjunction with a belt to separate extraneous iron particles from grains, cereals, and other commodities.

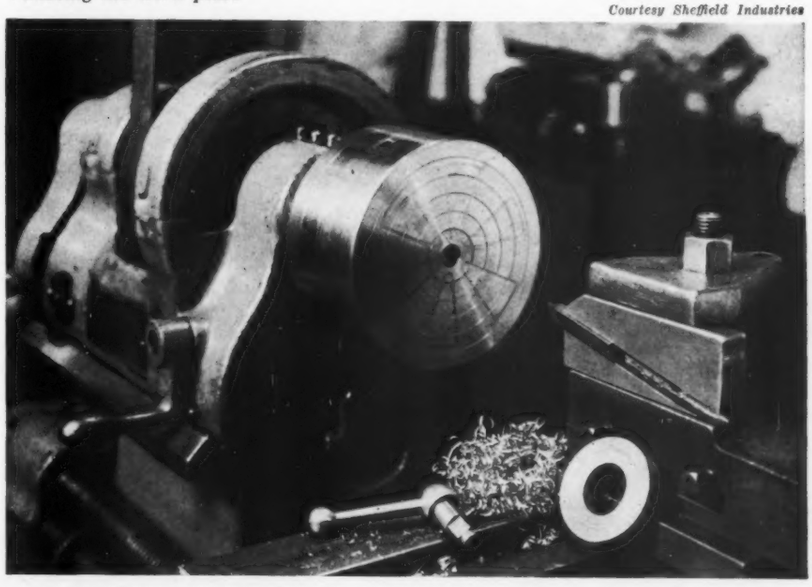
Artifices Change Flux Density

For permanent-magnetic applications requiring a change in flux density, various artifices can be used to achieve this effect. One of the more common methods alters the air-gap length, usually by means of an accurately calibrated micrometer-screw adjustment. In other instances, it is possible to use a magnetic shunt, comprised of nothing more than an iron bar of small cross-sectional area, to by-pass the air gap. Two examples of the latter arrangement are a quick-release hand magnet and a circular magnetic chuck, both made in England. The former, used to pick up nails, staples and the like, has a thumb lever which actuates a chuck releasing the material. The chuck operates on a similar principle but, instead of using separate shunts, its pole pieces are shifted with respect to the magnets so that they act as shunts and release the work piece.

Other examples of applied permanent magnets are numerous and establish beyond all doubt the usefulness of the alloy magnet steels. Each problem can be handled best by taking advantage of the practical measures which contribute to efficient design. For this purpose attention is invited to the equations and suggestions presented in Parts I and II of this article. The merits of the intended application will then be apparent to the designer.

Through an ingenious arrangement, the pole pieces of this permanent-magnet chuck can be rotated with respect to the magnets until they act as magnetic shunts, thereby releasing the work piece

Courtesy Sheffield Industries



ELECTRIC AUTOMATIC

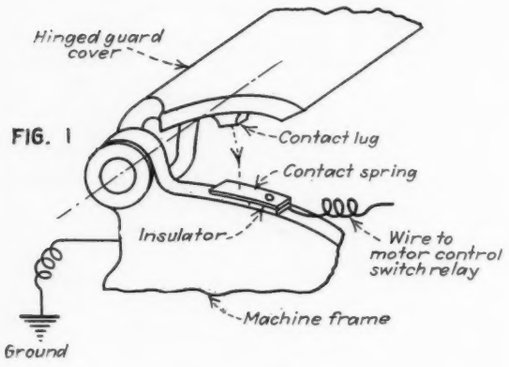


FIG. 1

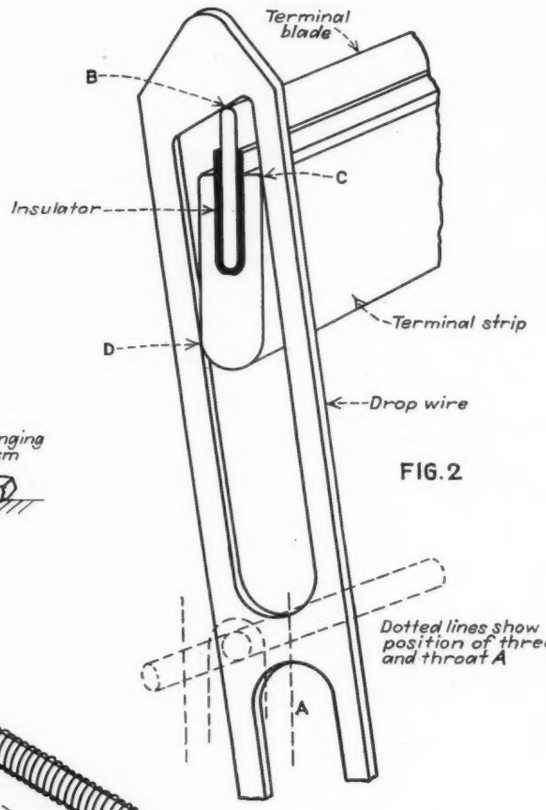


FIG. 2

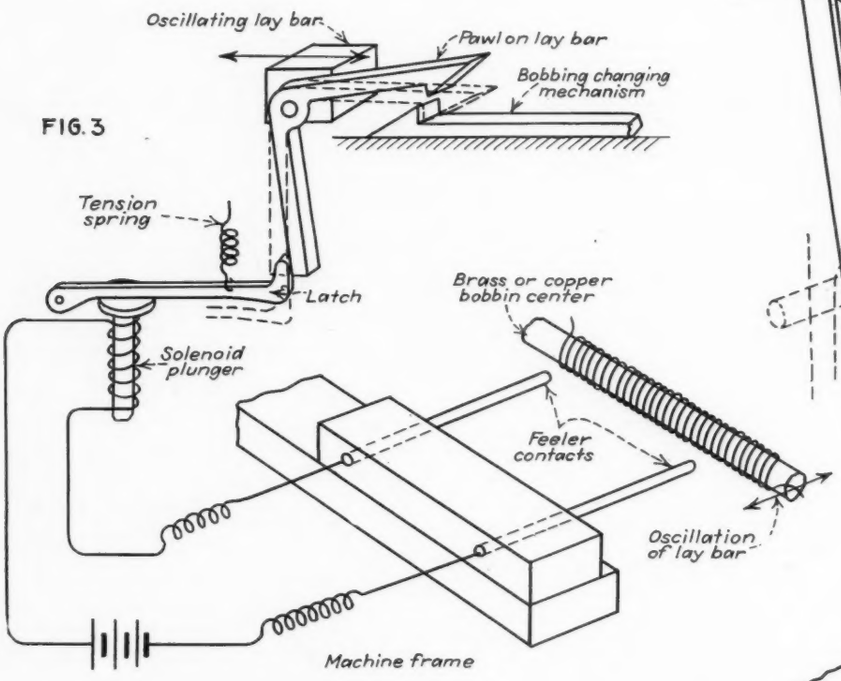


FIG. 3

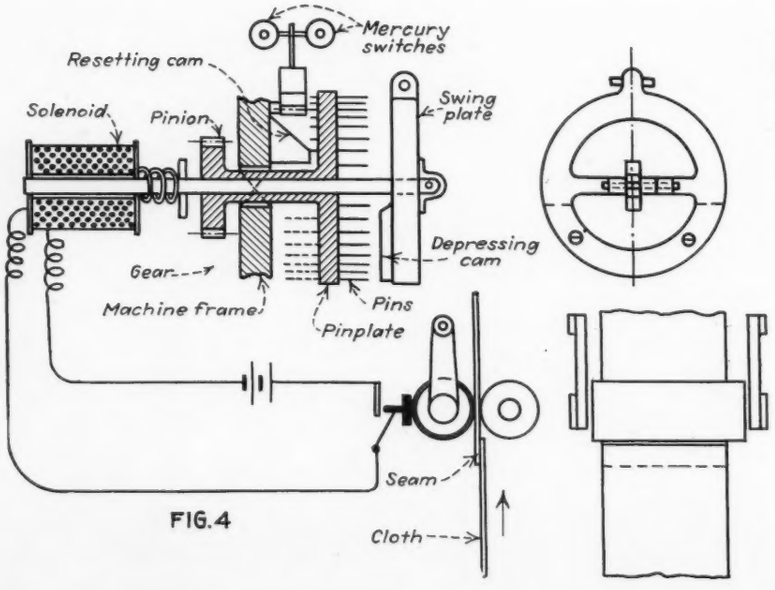
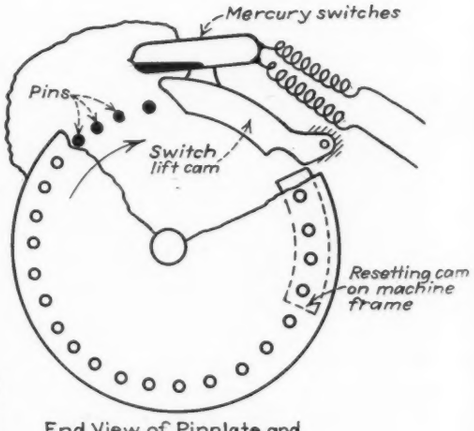


FIG. 4



End View of Pinplate and Mercury Switches

STOP MECHANISMS

Arrangements and designs diagrammatically illustrated here were taken from packaging machines and textile machines. Modifications of them to perform other operations can be easily devised

FIG. 1—Safety arrangement used on some machines to stop motor when guard cover is lifted. Circuit is complete only when cover is down, in which position contact lug has metal to metal connection with contact spring, completing circuit to relay.

FIG. 2—Electrical 3-point wedging type "warp stop" shown after thread has broken and drop wire has fallen and tilted to close circuit. Dotted lines indicate normal position of drop wire when riding on thread. When thread breaks the drop wire falls and strikes the top of terminal blade at *B*, the inclined top of the slot causing a wedging effect which tilts drop wire against the terminal strip at *C* and *D* intensifying the circuit closing action.

FIG. 3—Bobbin changer. When bobbin is empty the feeders contact the metal bobbin center, completing the circuit through a solenoid which pulls a latch that causes bobbin changing mechanism to operate and put a new bobbin in the shuttle. As long as the solenoid remains deenergized, the pawl on the lay bar will be raised clear of the hook on the bobbin changing mechanism.

FIG. 4—Control for automatic shear. When a seam of two thicknesses of cloth passes between the rolls the swing roller is moved outward and closes a sensitive switch which energizes a solenoid. Action of solenoid pulls in an armature the outer end of which is attached to a hinged ring to which a cam plate is fastened. The cam plate depresses a number of pins in a rotating plate. As the plate rotates the depressed pins lift a hinged cam arm on which are mounted two mercury switches which, when tilted, complete circuits in two motor controls. Fastened on the frame of the machine is a resetting cam for pushing the depressed pins back to their original position. In this arrangement two motors are stopped and reversed until seam has passed through rollers, then stopped and reversed again.

FIG. 5—Electric stop for loom. When thread breaks or slackens the drop wire falls and contact *A* rides on contact *C*. The drop wire being supported off center swings so that contact *B* is pulled against inner terminal strip *D* completing solenoid circuit.

FIG. 6—Automatic stop for folder or yarder to stop machine always in the same position when a seam in the cloth passes between the rolls. A seam passing between the rolls causes swivel mounted roll to lift slightly. This motion closes contacts in sensitive switch which throws relay in control box, so that the next time the cam closes the limit switch the power of motor with integral magnetic brake is shut off. The brake stops the machine always in the same place.

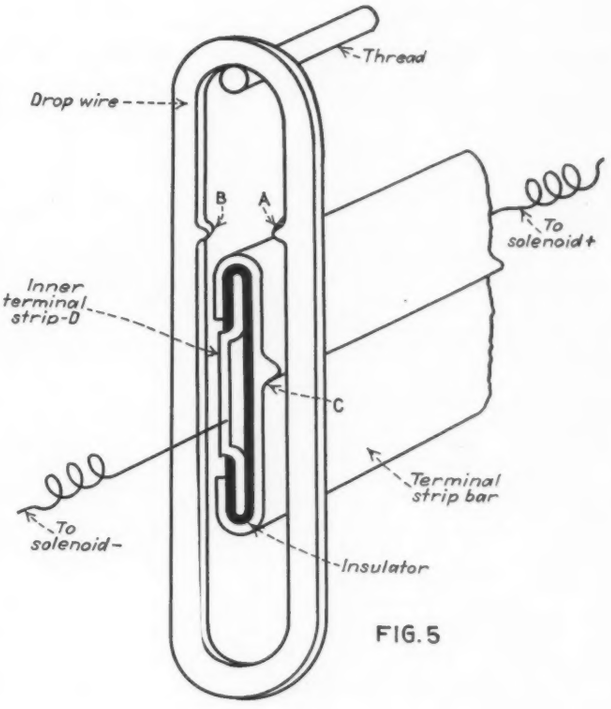


FIG. 5

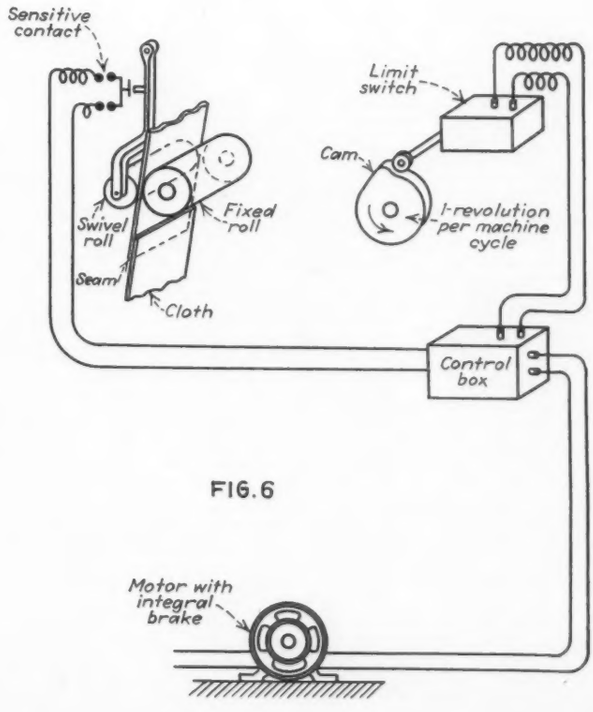


FIG. 6

MODERN LIGHT RELAYS

And What They Can Do

CARL P. BERNHARDT
Electronic Application Engineer
Westinghouse Electric & Manufacturing Company

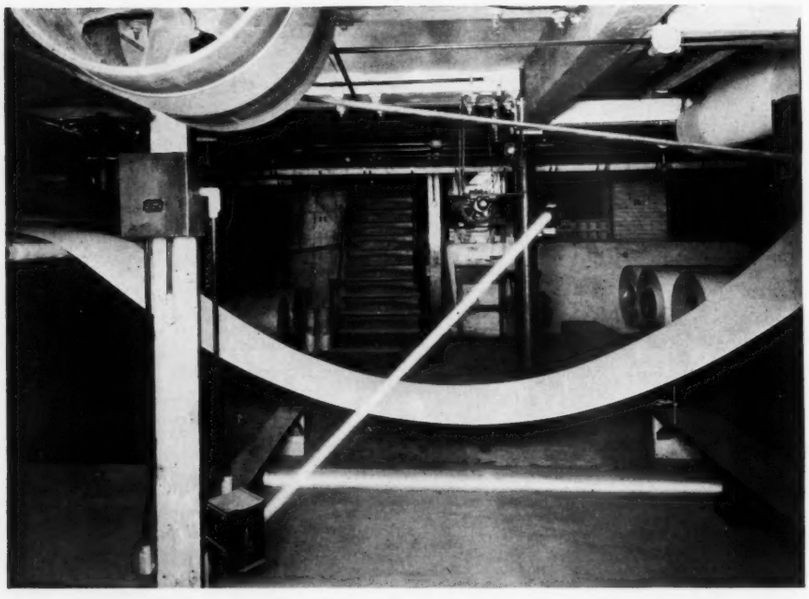
Dividing equipments now available into four main classifications as to circuits shows how electronic relays can be applied to suit various duties, sensitivities and speeds

USES of electronic tubes in telephony or radio are so well known and so general that for some time their applications in these fields have been made strictly on an engineering basis. Until recently, however, their novelty and a lack of familiarity with them on the part of engineers in other fields have in many instances clouded further applications of them behind a multiple curtain of expectation, fear and admiration. Nevertheless their field of application to industrial problems has continually broadened and the great majority of their past applications have been successful to the extent that many other similar installations have been made. This is, after all, the final proof as to whether any one application is fundamentally a sound and economic one.

The earliest and simplest industrial applications of electron tubes were associated with photoelectric or light relays. These devices, since their introduction, have been considerably improved and refined and are now available in a number of different types and forms to meet various application requirements. Typical modern equipments now on the market may be divided into the following four main classifications:

1. A simple, inexpensive light relay, entirely self-contained, for low-current control applications where high sensitivity and fast action are not essential, such as for operating magnetic counters, indicating lamps, and alarm gongs.
2. A light relay that is sturdy and capable of operating under severe temperature, dust, vibration and other adverse conditions, and of handling control currents of the order of 10 amp. at 220 volts.
3. A sturdy light relay that, under severe conditions, is capable of operating continuously at high rates of speed, such as at 100 or more operations per minute.
4. A light relay capable of operating from a change in illumination which occurs in 0.002 sec. or less.

Control of these light relays can be effected by either an increase or decrease in normal illumination, depending on how the connections are made to the phototube. This is a feature generally included in all standard equipment.



The slack in the sheet between two machines used in making coated paper is held within definite limits by light beams directed over and under the sheet. Photoelectric relays actuate a motor-operated rheostat to correct the speed of the motor driving one of the machines whenever either of the light beams is interrupted by the loop

Simple Relays

Relays of the first classification, as indicated, are for relatively simple applications where heavy duty is not involved and consequently a simple combination of relay elements can be used. In the equipments made for such use, a phototube controls a standard radio-type amplifier tube that operates a telephone-type relay directly. These, together with the other incidental parts required, are all mounted in a small sheet metal inclosure, the cover of which has an aperture in it permitting the phototube to receive the illumination from the light source. The assembly therefore comprises an entirely self-contained, compact unit readily adaptable to those applications for which its characteristics are suited.

However, this simple combination of relay elements naturally has its limitations. The amount of current that the unit can handle is limited by the capacity of the telephone-relay contacts to a maximum of about 1 amp. non-inductive alternating current load. The speed of operation is limited by the pick-up and drop-out time of the telephone relay and, in general, the light beam must be either established or interrupted for at least 1/15 sec. in order to assure positive operation.

Fundamentally, the plate or output current of a radio-type amplifier tube varies as the controlling grid voltage is made more or less negative. This plate current is generally of the order of 25 milliamp., but, because of changes in phototube illumination, it may vary over

a range of from 10 to 25 milliamp. As a result, the telephone-relay air gap and spring tension must be adjusted to obtain proper operation with this change in operating current. The calibration of the light relay depends, therefore, on the uniformity of the pick-up and drop-out values of the telephone relay, which can be considerably affected by dust and vibration.

Moreover, with all of the elements including the phototube grouped within one inclosure, a problem often arises when it is desired to apply this type of relay to a machine where the space available is restricted. For such applications a more desirable arrangement is to have the phototube mounted separately in a suitable small housing at or in the machine and connected to the amplifier and associated equipment by means of an extended cable. Because of the electrostatic capacity between the wires of this phototube cable, which may be 10 ft. or more in length, more current may flow in the phototube circuit than would normally be passed by the phototube itself. A different type of circuit arrangement is therefore required.

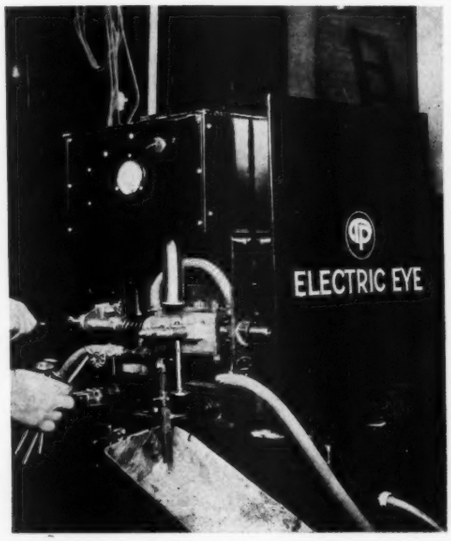
To meet these conditions, light relays of the second general classification can be used. They have a sensitivity of 3 foot-candles and are so designed that the phototube can be located as far as 10 ft. away from the main control cabinet, a special high-insulation resistance cable being supplied for the inter-connection. Direct current is obtained from a small copper-oxide rectifier and is used to excite the phototube; hence the electrostatic capacity between the phototube leads becomes of negligible importance. The phototube is arranged to control a thyratron tube instead of a radio-type amplifier tube, assuring long life of the main operating element and improving the reliability of operation.

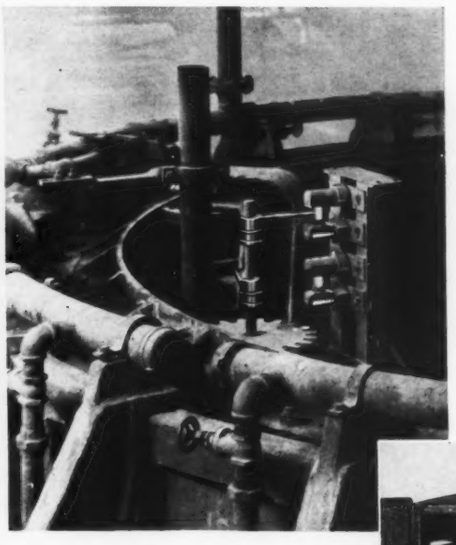
The characteristics of the thyratron tube are such that it passes either its maximum output or zero current. Moreover, it will pass directly a current of the order of 2/3 amp. and deliver this to a load, such as the operating coil of a contactor, at any voltage desired. Therefore, a sturdy, reliable contactor can be directly controlled. Since the thyratron tube current controlled by the phototube is either at a maximum or at zero, vibration cannot affect the positive operation of the contactor used, which is capable of handling 10 amp. at 220 volts.

Relays of the second general classification can be used for a multitude of purposes as control devices and as limit switches where mechanical contact with an object such as a heated ingot or a fragile material such as a sheet of paper would be impossible and impractical. In the manufacture of paper containers, for example, they can be arranged to operate when a production line is full, thus stopping the feeding machinery and preventing damage of the finished product through jamming in the feeding lines. In steel mills, they can be used on sheetcatchers to initiate the operation at the end of a pass, taking the hot sheets from between the rolls and returning them over the top roll for another pass. In the heat-treating of valve stems, they are employed as pyrometers to "watch" the piece while it is being electrically heated and, when the desired color temperature is reached, actuate a tripping mechanism that drops the piece into a quenching bath.

Such relays can also be used to regulate the speed of a motor in a wire-drawing process or paper-coating machine. Two of the relays are provided and they act as limit switches, operating when a loop in the material ahead of the drawing-roll stand becomes either too short or too long. The contactors of the relays actuate a motor-operated field rheostat to control the speed of the reel motor, thus maintaining the loop of material within certain limits and preventing an actual break in the material if the loop becomes too short or marring of its surface if the loop becomes too long.

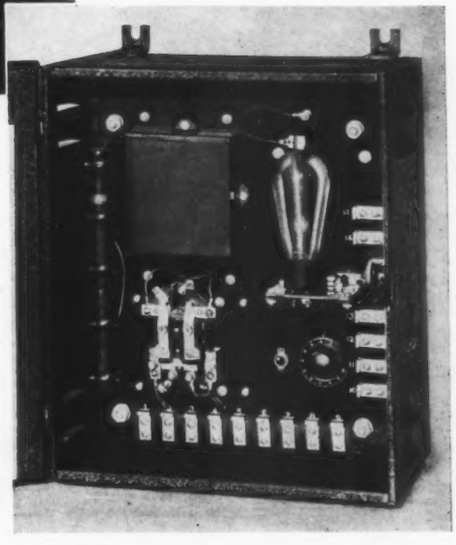
An example of the type of applications requiring relays of the third gen-





In hardening valve stems, this photoelectric equipment watches the tip of the valve while it is being electrically heated and, when the desired color temperature is reached, a tripping mechanism operates and drops the valve into the quench tank

Electronic control assures precise stopping of the heavy turntable used in casting copper cakes for wire-drawing. Two light beams are used, interrupted by two rotating "flags" geared to the turntable. Interruption of the first beam applies regenerative braking. Interruption of the second completes the job, halting the machine with the molds accurately centered under the pouring spout



Modern high-speed, "lock-in" type of electronic relay, using a thyratron tube with direct current impressed on anode

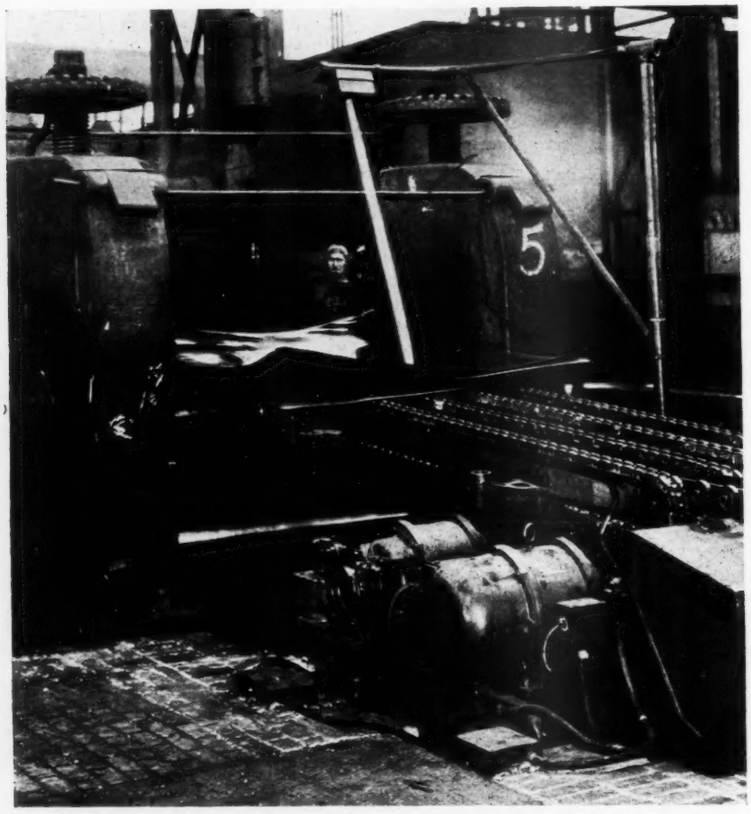
eral classification is an inspection device used in connection with the automatic weighing of filled food containers being handled at a rate of 100 or more per minute. The light relay must be capable of operating continuously at this rate and also must have sufficient sensitivity to detect a very small change, of the order of 0.010 in., in the position of the weighing-scale beam. The relay used has an amplifier tube interposed between the phototube output and the grid circuit of the thyratron tube in order to provide the increased sensitivity required. In the inspection application, the phototube receives its illumination through a ¼x0.020 in. aperture. Thus a 0.010 in. movement of the weighing-scale beam can increase the illumination on the phototube 50 per cent. The change in output of the phototube is stepped up by the amplifier tube and applied to the thyratron tube. Then, in order to obtain a high rate of operating speed continuously, the output of the thyratron tube is used directly to energize a solenoid-operated air valve, thereby eliminating the inherent time lag and maintenance of a control contactor.

Relays of the fourth general classification are used where operation is initiated by a momentary change in light intensity occurring in a small fraction of a second. The basic difference between this type of equipment, which is capable of being operated by a light impulse of only 0.0005 sec. duration, and equipment of the second classification is that the direct current obtained from the self-contained copper-oxide rectifier is applied to the anode of the thyratron tube as well as to the phototube. It is characteristic of thyratron tubes that, once the grid permits the tube to pass current, the grid loses control and the current continues to flow until the voltage applied to the anode falls to zero or is reversed in polarity. When the tube is used on alternating current this happens every half cycle and the grid, therefore, regains control every half cycle and can be used either to permit or to prevent the flow of current on succeeding positive half cycles.

"Lock-In" Controller

Thus a light relay with a thyratron tube arranged to operate when the phototube is illuminated will pass 60 half cycles of current if the phototube is illuminated for one second and the a.c. line frequency is 60 cycles. However, if d.c. is applied to the anode of the thyratron tube and an impulse from a phototube is impressed upon the control grid, the tube operates and continues to pass current until the applied d.c. voltage from the rectifier is momentarily removed. It is because of this characteristic that these equipments are often called "lock-in" light controllers. The thyratron tubes used can be operated or ionized in 0.00001 sec., or will respond to surges occurring in this length of time, and they will cease operating or deionize, under proper conditions, if the voltage is removed for only a 0.001 sec. interval. For greater sensitivity in certain applications, relays of this classification may utilize a radio-type amplifying tube interposed between the phototube and the d.c.-operated thyratron tube, but they will then be slower in response because of the time constant of the added tube circuit.

Applications of these exceptionally quick-acting relays are made wherever the time element in a problem necessitates their use. In a large copper refinery, as one example, they are employed to bring a large turntable to a precise stop at regular intervals on its periphery. Molds for making copper cakes to be used in wire-drawing are located on the turntable which must be stopped when the molds are directly under the pouring spout, so that molten copper will be prevented from hitting the sides of the molds and chilling. Mechanically operated limit switches did not afford sufficient accuracy. However, two light relays of the fourth classification were installed in conjunction with two rotating "flags" suitably geared to the turntable. When the first flag interrupts the light beam directed on the phototube of one relay, regenerative braking is applied to the motor driving the turntable. When the second flag cuts off the light to the phototube of the other relay, a mechanical brake stops the turntable at the exact pouring position.



In a steel mill, this sheetcatcher swings up and down at the command of a photoelectric relay, taking the hot sheets from between the rolls and returning them over the top roll for another pass

Service Experience

The service experience gained in the various applications mentioned has been extremely satisfactory. There need be no hesitancy in using light relays for any application where the use therefor is definitely warranted. It is logical to expect that in the future such equipment will be used to an even greater extent than in the past and that thyratron tubes will be commonly used to operate directly such power-consuming devices as solenoids, brakes, clutches and single-direction or reversing d.c. motors. The use of electronic tubes for motor control has been confined mainly to accurate regulation of speed. In this respect, it appears that their most desirable function at the present stage of development is remote control of motor speed by field regulation, although a few installations are in service where power tubes are actually handling the armature current of the motor.

Question and Comment

Wear Load Values for Spur and Bevel Gears

JOHN G. URBANIK
Rochester, N. Y.

It has been customary both here in America and in England to use the following basic formula for the wear load values of spur and bevel gears.

$$\frac{W}{f} = k\,D^n$$

W = tangential load in lb.
f = face width in inches
k = proportionality constant
D = pinion pitch diameter
n = exponent, usually ½ or 1.

This equation has serious defects from a mathematical point of view. It will not stand the dimensional test which requires that the fundamental magnitudes of mass, length and time appear to the same degree in both sides of the equation. Dimensional analysis dates back at least to the time of Jacques Fourier, the eminent French mathematician, and is well accepted by the modern mathematical physicist. This check prevents the writing of an absurd equation such as: dollars × cents = inches. If m is the mass, l the length, and t the fundamental magnitude of time, the wear load formula reduces to the following equality among the dimensions, which obviously is not true.

$$\frac{m}{l} = 1^n$$

Without elaborate consideration of the problem, the following formula is suggested as a starting point. It is dimensionally accurate, although it has not been checked against any published data on wear loads.

$$W = \frac{k \cos \phi}{\sqrt{1 + (n/N)^2}}\,SD$$

W = tangential load in lb.
f = face width in inches
k = a proportionality constant
ϕ = pressure angle
S = strength factor, usually tensile strength in lb. per sq. inch
D = pinion pitch diameter in inches
n/N = gear ratio
n = number of teeth in pinion
N = number of teeth in gear.

It is interesting to note that in this type of wear load formula, the time element is lacking in the left-hand side of the equation and prevents the introduction of a velocity factor in the right-hand side unless the tensile strength factor is changed to one, which more nearly represents the actual conditions in gear tooth contact, namely, variable sliding and compression.

Gear-Bore Proportions

PAUL H. BLACK
University of Illinois

In order to proportion a gear so that it will be equally strong against failure by fracture of a tooth and fracture of the hub, the critical stress at the tooth fillet should be equal to the critical stress at the keyway corner.

As a contribution to this field of study, where reported results have not been extensive, an investigation into the relative stresses in solid spur gears was made using the photoelastic method with pyralin models of gears having the Brown and Sharpe form of teeth. Results are reported in Bulletin No. 288 of the University of Illinois.

The first part of the investigation established, on the basis of lowest stress, the best location of the keyway, that is, whether the keyway should be placed directly under a tooth, under a tooth space, or in an intermediate position. The result was determined by using pyralin models of gears, all of 3-in. pitch diameter, with the keyways located so that their center lines occupied various positions. Models of 12, 15, 18, 21 and 24 teeth were used, each with bores ranging from 1 in. to 1⅞ in., increasing by ⅛ in. increments. The keyways were formed to accommodate square keys with sides one-quarter of the shaft diameter.

The stress at the keyway corner in each case was determined and used for establishing the best location of the keyway. It was found that in all cases the best location for the keyway was that in which its centerline bisected a tooth space. The accompanying illustration shows this most favorable location.

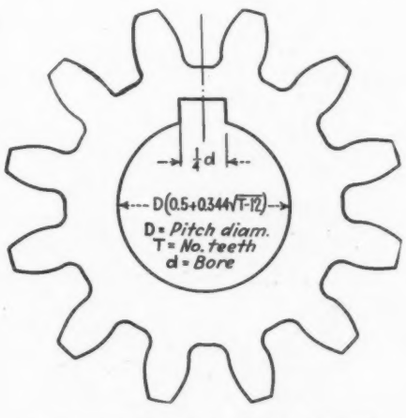
The second part of the investigation determined the diameter of bore which would allow the same stress at the tension fillet of the tooth and at the keyway corner. Models of exactly the same description as those used in the first part of the investigation were selected and the keyway was placed at the previously determined most favorable location.

On the basis of geometrical similarity of the tooth profiles of all gears with the same number of Brown and Sharpe teeth, the maximum bore as found by the investigation may be expressed as a function of the pitch diameter and the number of teeth. The following equation satisfies very closely the experimental results:

$$d = D(0.5 + 0.344\sqrt{T - 12})$$

d = Maximum bore
D = Pitch diameter
T = Number of teeth

The equation may be applied to gears with a square key having sides one-quarter the shaft diameter and from 12



Gear proportioned for equal strength at teeth and at hub

to 24 teeth, this being the range covered in the investigation. For a number of teeth greater than 24, T may be assumed as 24 to obtain approximate results. The twelve-tooth gear in the illustration has a bore proportioned by the use of the equation.

Stress concentration factors for Brown

and Sharpe gear teeth were determined. These factors, based on the Lewis equation, vary from 1.47 to 1.35 at the tension fillet for 12 to 24 teeth respectively.

In the bulletin, limitations of results and guides to application are discussed. A limited number of copies are available for distribution.

Plating Beryllium-Copper

To the Editor:

Following the item which appeared in the News section of *P.E.* for April 1936, concerning the use of cast beryllium-copper molds for producing small plastic parts of intricate design, E. N. Schmitt and K. N. Atwater commented, in the May and August issues respectively, on the possibilities of greatly increasing the life of such molds by chromium-plating them. To the writer it seems very likely that a plate of chromium on beryllium-copper, though easy to apply, would not be very strongly adherent or wear-resistant. However, as a suggestion, it might be possible to increase the wear-resistance considerably by first plating a light coat of nickel on the beryllium-copper and then laying the chromium on top of the nickel, as a cement between the other two.

There are a number of instances in which a weakly adherent metal plating has been rendered more strongly adherent by the interposition of a plate of a highly soluble metal. Probably there are few if any pairs of metals which cannot be made to unite satisfactorily by the use of some third metal or alloy.

The strength of adhesion of a plate of one metal on the surface of another, as in the case of welds between two different metals, seems to be closely related to the solid solubilities of the respective metals in each other. The solubility of chromium and copper in each other is known to be limited. The writer has no data on the inter-solubility of beryllium and chromium, but, because of their crystal structures, it is not probably that they have any great solubility in one another, even if the beryllium were present in such quantity and distribution as to influence the result materially. Nickel, however, dissolves all three metals and is therefore suggested.

—Leo G. Hall
Allegan, Mich.

Resistance of Belt to Slipping Shown by Chart

SALVATORE F. CAVALLI
Dover, N. J.

As a convenient means of determining the resistance of a belt to slipping, the accompanying nomagraphic chart was constructed which, given the tension on the tight side of the belt and the angle subtended by the arc of belt contact on the pulley, makes available the tension on the slack side. The difference between the tension on the tight side and that on the slack side gives the resistance of the belt to slipping.

In laying out the chart the following basic formula, which disregards centrifugal forces, was used:

$$\frac{T_1}{T_2} = e^{f\alpha}$$

T_1 = Tension on tight side
T_2 = Tension on slack side
f = Coefficient of friction between belt and pulley
α = Angle subtended by arc of belt contact on pulley, in radians
e = 2.7182+, Base of natural logarithms

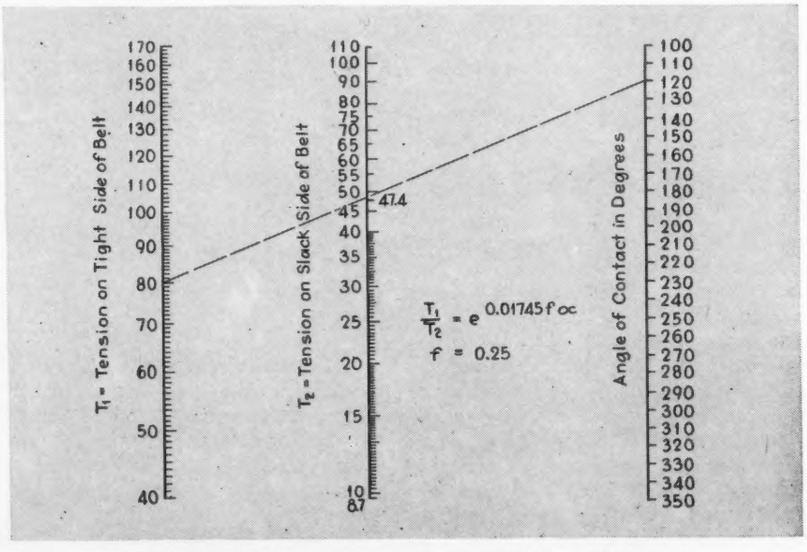
It will be noted that the formula gives the ratio between the two tensions; consequently any desired units may be used and, if the one tension is expressed in lb. per in. belt width, the other tension will necessarily be in the same units.

Since radians are inconvenient to use in practice and since degrees can be readily converted to radians by multiplying by the factor 0.01745, this factor is included in the exponent of the formula actually used in constructing the chart, so that the value of α on the chart is expressed in degrees.

The coefficient of friction selected for use in constructing the chart was 0.25, which is approximately the value ordinarily used for leather on iron. If, however, it is desired to use the chart for materials having a different coefficient of friction, the actual angle of contact can be multiplied by that coefficient and divided by 0.25 to obtain an equivalent angle of contact for use on the chart.

As an example, let us consider a belt having a tension of 80 lb. on the tight side and a 120 deg. angle of contact. To find the tension on the slack side, a line is drawn from 80 on the tight-side tension scale to 120 on the contact-angle scale. This line intersects the slack-side scale at 47.4, which is the number of lb. tension on that side of the belt.

In the above example it is, of course, taken for granted that the belt is leather and the pulley iron. If two materials having a coefficient of friction of 0.50 were used and the angle of contact were 60 deg., then the equivalent angle of contact would be 120 deg. and the same line on the chart would solve the problem.



Nomographic chart giving resistance of belt to slipping

More on Geometric Progressions of Speeds

To the Editor:

With much interest, I have read the criticisms of Mr. J. Decker and Mr. Francis W. Shaw in the March issue of *Product Engineering* relative to my article in the December issue on "Modifying Geometric Progressions of Speeds."

Referring to the charts by Mr. Decker, permit me to state it seems somewhat

strange that Fig. 1, 3 and 4 look fine; whereas Fig. 2, supposed to represent "Modifying Geometric Progression of Speeds," looks bad indeed. Yet, it will be found that, if given proper thought and consideration, the method I described will accomplish all I have claimed for it. Mr. Decker is in error when he states that my method has an irregular speed drop. The method has no more irregular speed drop than any other progression as portrayed by him in his charts. This can be verified by a glance at my original layout showing the three different cases. Do you notice any irregularity there? No, you do not. So why does this supposed irregularity appear?

Mr. Decker has the idea of putting the slower speeds even closer together and the faster speeds further apart. These are, however, not the most economical speeds, or what we would call the "ideal" speeds, and that's the real fault with many of our machine tools today. His remarks indicate that he is inclined to lean toward hard and fast rules relative to speeds in geometrical progression; whereas many times it is much better to deviate somewhat. He also mentions that with the pending standardization of speeds, any arrangement differing from the one based on geometrical progression seems to be out of the question. That is a rather positive assertion, and I, for one, would not rely entirely on this standardization, for I have seen several standards which in practice are no standards at all because they do not cover the field properly. And so it would be with any set of standards for geometrical progression. Deviation from any standard is always permissible if such deviation is in a direction to better meet the requirements of the case on hand.

Referring now to Mr. Shaw's criticism, I will again have to refer to my original chart. The conditions he points out do not exist. He has taken an arrangement of gears in such a manner as to make it appear that it would be impossible to retain the original speeds I gave. I suggest that he take the geometrical speeds as given in Table No. 1 of my original article and work out the problem in the same manner as he did by taking the values from Table No. 2. By this method he will find that Table No. 1 will also be wrong. As a matter of fact, neither Table No. 1 nor No. 2 works out as he mentions and shows by his tabulation. It is obvious that a condition such as he mentions cannot and does not exist. —Edward J. Rantsch
Hollis, N. Y.

To the Editor:

In reference to Mr. Rantsch's comments regarding my criticisms of his suggestion, I fear that he has entirely missed the point of my discussion. I do not doubt that many times it is necessary to deviate from any accepted series and by no means would I apply a rule for the sake of the rule where it was not warranted. However, I am in favor of standardization, where standardization is possible. Thus far, I have not seen any suggestion which, when used as the basis for speed standardization, could in all of its aspects improve upon the geometrical progression ratios.

It is not my idea to group the slower speeds closer together at the larger diameters, although I approve of it. The idea came from the desire to do more economical metal cutting at the larger diameters and slower speeds. This is one reason why the arithmetical progression for speed-step distribution has been abandoned in favor of the geometrical one and the tendency has been enhanced by the attempts to use logarithmical speed-step distribution. All this was clearly brought out by the diagrams shown in my previous discussion, without trying to make one method look "fine" and the other one "bad." There would not be any reason for such tactics in a discussion of this nature.

However, Mr. Rantsch can easily calculate and prove to himself that his series has an irregular speed drop and that is why I tried to prove it with my diagrams. Although they were not in any way distorted to favor one or the other method, I admit that through a slight error the drop indicated in Mr. Rantsch's series at 101 r.p.m. is somewhat displaced. Nevertheless, the fact still remains that his suggested series has an irregular speed drop.

The accompanying table gives a comparison of both the nominal speed drop and the percentage of speed drop for three speed steps, using the arithmetical, the geometrical and Mr. Rantsch's modified method. In the arithmetical series the speed drop is constant as far as the nominal drop in speed is concerned, but in per cent the speed drop is an increasing variant. In other words, as the speed decreases, the percentage drop increases. In the geometrical series the nominal speed drop is a decreasing variant while the percentage drop is a constant. In the logarithmical series (not tabulated), the ratio from step to step drops as the speed decreases.

As the table shows, Mr. Rantsch's modification has a characteristic of the geometrical series in that the nominal

Comparison of the nominal speed drop with the percentage of speed drop, for three methods of speed-step distribution

Nominal Speed Drop Constant	Percent Speed Drop Increasing
ARITHMETICAL SERIES	
(1) $200 - 188 = 12$	(1) $\frac{200-188}{200} \times 100 = 6.00$
(2) $188 - 176 = 12$	(2) $\frac{188-176}{188} \times 100 = 6.38$
(3) $176 - 164 = 12$	(3) $\frac{176-164}{176} \times 100 = 6.82$
GEOMETRICAL SERIES	
Nominal Speed Drop Decreasing	Percent Speed Drop Constant
(1) $200.0 - 171.6 = 28.4$	(1) $\frac{200.0-171.6}{200.0} \times 100 = 14.2$
(2) $171.6 - 147.4 = 24.2$	(2) $\frac{171.6-147.4}{171.6} \times 100 = 14.2$
(3) $147.4 - 126.5 = 20.9$	(3) $\frac{147.4-126.5}{147.4} \times 100 = 14.2$
MODIFIED SERIES	
Nominal Speed Drop Decreasing	Percent Speed Drop Increasing
(1) $200 - 181 = 19$	(1) $\frac{200-181}{200} \times 100 = 9.50$
(2) $181 - 163 = 18$	(2) $\frac{181-163}{181} \times 100 = 9.95$
(3) $163 - 146 = 17$	(3) $\frac{163-146}{163} \times 100 = 10.40$

speed drop is a decreasing variant and it also has a characteristic of the arithmetical series in that the percentage drop is an increasing variant. It is the latter characteristic which determines the usefulness of a series.

Mr. Rantsch, I am certain, would find it interesting to read Dr. Ing. M. Kronenberg's book, "Zerspanungslehre," Prof. Schlesinger's "Wesen & Auswirkung der Drehzahlnormung" and Dr. Ing. Germars "Normdrehzahlen."

From the practical point of view, it may be mentioned that the speeds of almost all German machine tools are standardized today for the benefit of manufacturers and users.—J. DECKER
Cincinnati, Ohio

To the Editor:

Mr. Rantsch's comment on my criticism leaves the problem where it was. He has failed to grasp the real implication of my analysis of his tables. May I repeat, therefore, in different and unmistakable words that ordinary arrangements of gearing do not conveniently permit speed ranges other than the geometrical.

As far as I am aware, there is but one gear arrangement of a simple nature by which the proposed series of speeds can be conveniently achieved and even that would demand some gear pairs of rather extreme ratio. I refer to the scheme of gearing sometimes embodied in lathes with fixed "change" gears, comprising either a long pinion or a cone of gears meshing through a tumbler gear with a cone of gears either on the screw or connected with it.

Now, it should be obvious that if a cone of gears on the primary shaft meshes with a cone of gears on an intermediate shaft, as in the 4/4 combination I have mentioned, and a second cone of gears on the intermediate shaft meshes with a cone of gears on the final shaft (a common and convenient arrangement), the total number of final shaft speeds will be 16 in this combination.

To simplify analysis, let the speeds of the final shaft, when the lowest-speed pair of gears on the primary and on the intermediate shaft are in action, be 10, 20, 30, 40. Then, I claim, the second four speeds must be in this same ratio; and the third and fourth four speeds also, for the ratio is controlled by the fixed ratio of the pairs of gears between the intermediate and the final shaft. There is, of course, another arrangement giving a similar result, as the reader will readily see, but it will not be considered at this time. In the arrangement under consideration, if the fifth speed is 12, the second four speeds will be 12, 24, 36, 48; if the ninth speed is 15, the third four speeds will be 15, 30, 45, 60; if the thirteenth speed is 20, the fourth four speeds will be 20, 40, 60, 80. And this is just what my Table II, in your March issue, was intended to show.

If I have led Mr. Rantsch to assert that the conditions I mentioned do not exist, simply because I made my first, second, third, fourth, fifth, ninth and thirteenth speeds tally with his, and not some other, I apologize, but it will be seen that the argument is unaffected no matter which speeds in his table and mine are made to agree. If I had accepted 20 as the lowest speed and 200 as the highest, the intermediate speeds even then would not have been as he gives in his Table II.

I should be much interested to have Mr. Rantsch work out a set of gears to yield his preferred speeds. I can assure him that there is never any difficulty in working out a geometrical set, though he seems to suspect that I should find trouble if I followed the manner I did.

Surely, however, no demonstration is needed of the possibility of always finding a geometrical set of gears. As a gear man, Mr. Rantsch undoubtedly knows that. Let us see, though, how easily we can find a set.

Let the speed of the primary shaft be N and the lowest required speed n. Then the required speeds will be n, nr, nr^2 . . . nr^{13}, nr^{14}, nr^{15}. But $n = Nab$, if a = the ratio of the lowest-speed primary gears and b = the ratio of the lowest-speed final gears. If the ratios of the other primary gears be ar, ar^2, ar^3, and the ratios of the other final gears be br^4, br^8, br^{12}, the combinations of these primary and final gears will give inevitably the speeds Nab, $Nabr$, $Nabr^2$ . . . $Nabr^{30}$, $Nabr^{14}$, $Nabr^{15}$; that is, n, nr, nr^2 . . . nr^{13}, nr^{14}, nr^{15}.

To calculate gears in any of these ratios, within the limits imposed by integral tooth numbers, is always possible as every designer of machine tools well knows, no matter what values be assigned to N, n, and r, the common ratio.

I await with interest a demonstration of Mr. Rantsch's method of calculating a set of gears fitting in with any ordinary arrangement of gearing and according with his proposed quasi-arithmetical series.

A final word. This discussion should interest C.M.M. of Cincinnati, Ohio, who in the Intimate Correspondence department of your April number deplored the publishing of contradictory articles. Without such publication is it not evident that someone would continue to hold incorrect views?
—FRANCIS W. SHAW
Whitworth, Lancs., England

[*Editor's Note: P. E.* assumes no responsibility for the opinions expressed in this discussion between Messrs. Decker, Shaw and Rantsch. However, if they or any other reader has additional views to present, the discussion will be extended in a later issue.]

Can You Work This One?

H. L. SMITH
Newark, N. J.

This Month's Problem—

The Commuter

THE RESIDENCE of a certain well-known executive is located a considerable distance from the nearest railroad station. Since his methods are very efficient, he has arranged for his chauffeur to leave the house every night at the same time and drive at a certain speed to the station, arriving just in time to pick up his employer, and then take him home at the same speed.

One evening, however, the executive completed his work early and caught a train which arrived at his station one hour sooner than his usual train. He started to walk towards his home, but the chauffeur met him part way there and then was able to get him to his house 30 minutes earlier than usual. For how long a time was the executive walking?

Solution to Last Month's Problem—

Railroad Personnel

SINCE the employee named Smith beats the fireman at billiards, the fireman's name is not Smith. The engineer's salary is one-third that of the man living nearest him, who must be Mr. Smith, since the engineer lives halfway between Mr. Jones and the brakeman, and Mr. Robinson lives farther away. Since the namesake of the brakeman is paid an $8,000 annual salary, which is not divisible by three, the brakeman's name cannot be Smith. Therefore, the engineer's name is Smith.

Reflecting the appearance value of color. A recent model built by International Harvester Company

COLOR SELECTION

for Appeal Plus Serviceability

RAYMOND LOEWY, *Industrial Designer*

In this first of a new series of color-illustrated articles, Raymond Loewy, consulting stylist for Studebaker, Sears Roebuck, TWA, Carrier Engineering, Greyhound Bus and numerous others, explains some practical considerations in the selection of colors

THE VALUE of color in vehicles for public transportation is recognized universally. Especially during the past five years it has been proven repeatedly that pleasing color finishes in buses, railroad coaches and airplanes are a definite factor in attracting passengers. And the attention given to colors in private automobiles is definite evidence of the value attached to color in that field. But perhaps it is not generally known that relatively recently it was discovered that color and finish have an important bearing on the salability of such purely utilitarian products as automobile trucks.

At first glance it may seem that it is rather far fetched to attach special importance to color and finish in automobile trucks. The old contention that appearance is a negligible factor in products and machinery that are primarily utilitarian, still abounds. And every time that an example of appearance value in production, construction or similar equipment is cited and proven, the retort of the die-hards is likely to be, "The exception proves the rule."

Be it as it may, a great deal about the value of finish and appearance was learned in the merchandising of automobile trucks. In selling trucks it was discovered that the opinions of the truck drivers were a big influence in the selection of the truck. This gave somebody the idea of paying special attention to the fittings, appointments and upholstery in the driver's cab. It was reasoned that truck drivers would like it if their truck

Proposed interior scheme for Transcontinental & Western Air, Inc., luxury liners showing day section

cabs were designed to be just as comfortable, convenient and pleasing as their pleasure cars. Such cabs would also reduce driving fatigue thereby contributing to fewer accidents and faster schedules. And it was also expected that with cabs of which the truck drivers could feel proud, relations between employer and employee would be improved and labor turnover reduced.

Recognizing the benefits of these features to the owners and the sales value of having the drivers praising the trucks, manufacturers have begun to fit the cabs with all the comforts and conveniences usually found in private cars. Thus, in some of the latest designs of trucks the cabs are fitted with cigarette lighters, ash-trays, deep cushions and arm rests. The instrument panels are designed with as much attention to appearance as is given them when designed for pleasure cars. Gear shift levers are fitted with molded plastic knobs and the floors have a suitable covering. Upholstery, necessarily of a color and texture suitable for hard service, covers the cushioned seats. Thus, the wants of the truck drivers for equipment of which they could be proud and a working space that catered to their comforts, were met.

What about the colors selected? What was the theory applied in the selection of the colors? The answer is simple. In this writer's opinion there is no sound theory that can be applied in the selection of colors for any product. Of course, there are definite relationships between colors with reference to color harmony and contrast, but there is no sound theory or theories that can be applied in the selection of the color scheme to be used insofar as public acceptance or favor is concerned. What the buyer likes and wants must be supplied.

Color Preference

An accident or whim may bring into public favor some particular color. A dressmaker in Paris may come out with a dress of an unusually "smart color." This color might appeal to certain industrial executives or may be called to their attention by some industrial stylists. The color may then be adopted for some mechanical product or other and thus a definite trend toward that color is created. The reasons why that color appealed to many people and became a "fad" are impossible to ascertain and undoubtedly innumerable factors entered into it.

Many possible reasons for the transient popularity of a certain color can be advanced. The contrast or harmony between that color and the current popular color may cause the latter to be displaced. The colors of the gowns worn at the coronation by the king and queen, the color tastes of an individual in the public limelight, the color adopted by a well known industrial company for its trade mark, the color of the background in some smart department store windows, the color of a menu on a fashionable trans-atlantic liner, or the color of a movie star's silk stockings may create a widespread demand for that particular color. And if the demand grows it may rise to a point where it becomes "the rage," then dies out to be replaced by some other color favorite that has won popular appeal by reasons equally ridiculous, or at least equally far beyond our understanding.

Choosing the right color, one that will meet public approval, can be done with a reasonable chance of success by a constant and close study of color fashions

and analysis of the repeating cycles of color popularity. Those who follow the trends in color popularity are in a position to make a generally accurate guess as to which colors will be in demand for the coming season. Although their prophesy is a guess it will be based on a fund of information not possessed by the average engineer and layman. Color preference determined by data on buying habits, as obtained from department store sales, is a definite indicator of color preference, but cannot be applied generally.

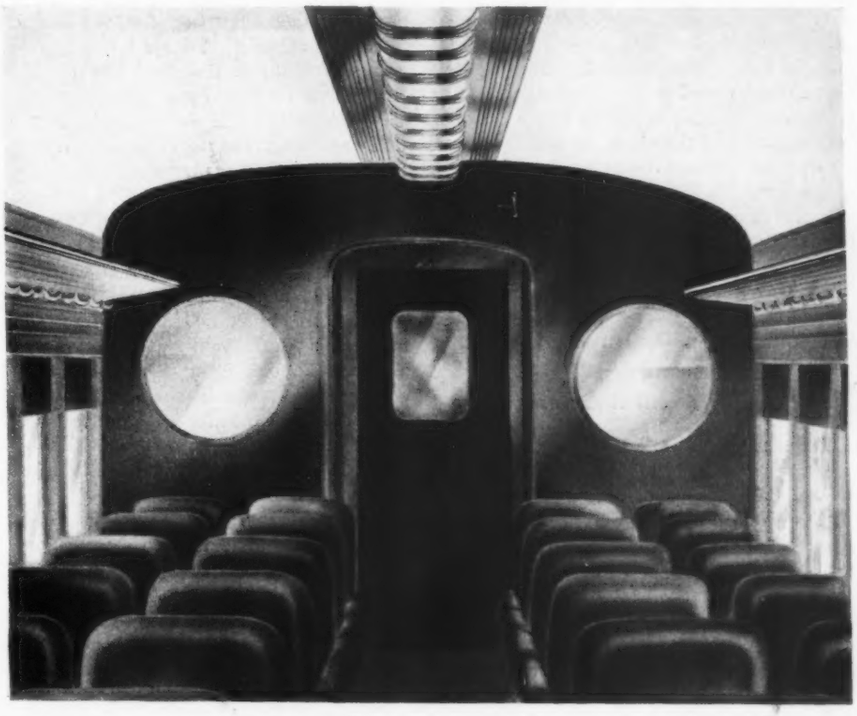
Esthetic values are not the only basis for the selection of colors. In many applications the color must be selected primarily on the basis of its service value. In the industrial field this will usually be the dominating factor. In selecting the pigment the problem is to get not only the best looking job as judged by the ultimate user of the product, but also to provide a finish that will be easy to maintain and will have a durability compatible with the life of the machine. It is with reference to these two factors that there are definite methods of procedure in the selection of the color and type of finish.

It is interesting to note that usually the user of the product places serviceability as one of the first things to be considered. The colors that do not glaringly show the dirt are the ones most popular with automobile owners. The color of the outside of passenger trains is usually a shade that does not readily show dirt or the grime from the smoke. In addition, there are other service factors which in certain applications may be more important than the ability to subdue dirt spots and grime.

Although the fact appears to be contrary to what one would expect, researches conducted for us by the Sherwin Williams Company have shown that in a fog white gives the greatest visibility for reflected light. Therefore, insofar as visibility in a fog is concerned white is the best color for marine craft. It also makes an extremely clean looking job and one that is easy to retouch because white can always be matched readily. On the other hand, tints such as oyster white are difficult to match and therefore should be avoided.

Unfortunately, practical considerations do not make it feasible to use white for the exterior of all marine craft. For example, on boats that are plying in a busy harbor where the atmosphere is heavy with soot and dust, the white would not last very long; it would soon look streaky and dirty.

A striking example of the styling of a marine craft is found in the S.S. Princess Anne, built by the Sun Shipbuilding Company of Chester, Pennsylvania, and now in service between Cape Charles and Little Creek, Virginia, operated by the Virginia Ferries Corporation. It is considered to be the most streamlined and the most advanced type of styling that has ever been adopted for marine craft. The forward end of the superstructure is well rounded. There is a semi-circle of windows at the forward end of the dancing salon on the main passenger deck, which makes the danc-



Pennsylvania railroad standard day coach, showing how new cheerful color trim and minor changes completely alter appearance

Cabs of latest designs of trucks are fitted and finished to make them comparable to the interior of pleasure cars

ing salon look bright and cheerful and permits a sweeping view of the sea from within.

The exterior of the Princess Anne is painted white with sufficient decorative treatment in red and blue to give contrast and a striking appearance. Stripes accentuate the streamlining and break the monotony that would result from the broad expanse of unbroken white.

Because airplanes now fly at high altitudes where the light is a great deal more intense and brilliant, subdued colors must be used in the interior. Therefore, relatively dark colors are used on the ceiling and the colors throughout are much darker than those used in buses, for example. This is particularly true for the colors being used in new planes designed for flying at altitudes of 20,000 to 30,000 ft., where the necessity of absorbing the brilliant light is important. Under such conditions bright colors would be entirely out of place.

Use of Natural Colors

As mentioned, the use of paint in airplanes is avoided because of the added weight. Therefore colors in the cabin of the plane are attained whenever possible by the natural colors of the materials of construction used. On sleeper transports leather is used exclusively for covering the partitions. The natural color of the leather, a shade darker than that used on the ceiling, is extremely suitable. Also, the material is light in weight and is a sound deadener.

In the control rooms of non-commercial planes the knobs on the levers and other controls are sometimes a brilliant Chinese red, being made of molded plastic, to give a strong contrast against the black, dull-finish panels.

Molded plastics are used for quite a number of fittings and appointments in the passenger compartment of the plane. An interesting situation arose in the use of molded plastic drinking cups of a pastel color. These cups became stained red around the rim and no amount of washing would remove the red stains. The particular plastic used was grease absorbent and it absorbed the lipstick stains left by the women who used the cups. Therefore in the selection of the molding compound for the cups it was necessary to find a plastic that not only would be resistant to water but also one that would not be affected by grease. It was also found that some of the plastics do not retain their colors satisfactorily, which problem also applies to paints and lacquers. The pigments fade when exposed to sunlight. Where permanence of color is important, the plastic should be selected with this factor in mind. With reference to lacquers, unless the color has permanence, it will be impossible to patch the finish after the product has been in service.

Maroon is one of the most difficult paint or lacquer colors to handle. It is not only difficult to apply, but after exposure to sunlight the color will usually spot and change. It discolors rapidly when subjected to high temperatures as on the top of the hood of an automobile.

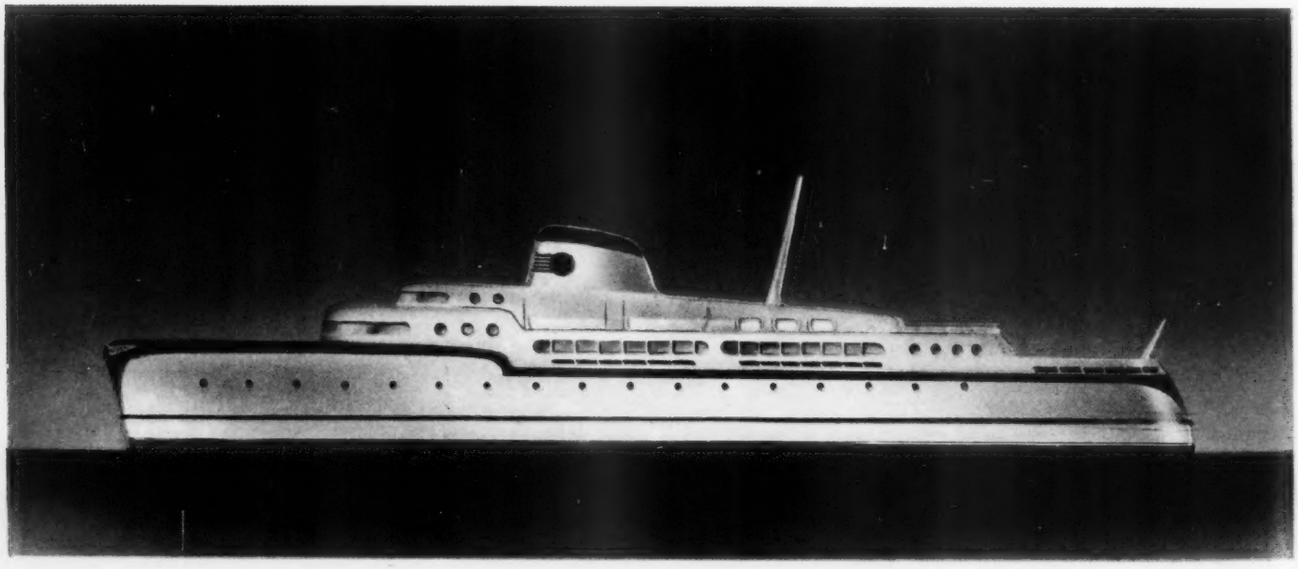
Among the colors that stand up best are fire-engine red, dark blues, black, and in fact practically all of the colors of the darker shades. This is a factor in the popularity of red and dark green for the outside color of automobile trucks. There is no theory as to which of these dark colors is preferable from the esthetic point of view. It is just a matter of taste, the final selection being largely influenced by service requirements and the standard colors that have been adopted by the company that is to use the truck.

Color Treatment

For the upholstery of buses, blue is one of the most successful colors in use today. Ceilings in buses are made white or light ivory in order to give good light reflection. The walls are made a slightly darker ivory. And because the floor covering always eventually becomes a grayish brown through use, it sounds reasonable to select that color for the back ground of the floor pattern.

With reference to exterior colors used on automobile passenger cars, the color treatment in conjunction with the lines of the body is one that should give the car a fast appearance. But in every instance the colors used must be those that are at the moment in popular demand in the various territories. For example, brilliant colors are acceptable in Florida or southern California, but would meet consumers resistance in Pittsburgh or Kansas City. Also, the brilliant colors now used on many taxicabs have condemned these colors for private automobiles. Blacks, dark blues and browns are the colors that are popular most consistently, while the tans and lighter shades have spasmodic periods of popularity.

S.S. Princess Anne operating as vehicle and passenger ferry between Cape Charles and Little Creek, Va. The distinct streamline appearance of this ship is further enhanced by the decorative color striping and trim. Exterior is mainly marine white with blue and black trim. Insignia on bow and stack is red, white and blue. Interior passenger quarters make generous use of color



News

Many New Machines and Design Improvements Seen at Milwaukee Foundry Show

More than 200 exhibitors displaying equipment in operation and a full program of technical sessions attract a record attendance at Annual Convention of American Foundrymen's Association.

THOSE attending the 41st Annual Convention of the American Foundrymen's Association had a hard job trying to divide their time to their best individual advantage between the fascinating exhibits, interesting technical sessions, inspection trips to local plants and numerous other activities. From the time the convention opened on Monday, May 3 to the closing on Friday, May 7, it was a continuous round of simultaneous events competing for attention.

Although almost all of the papers presented at the 26 technical sessions and round table discussions dealt with purely foundry problems, at least one paper was primarily for designing engineers rather than foundry men. This was a paper by Major R. A. Bull, the well-known consultant on steel castings, on the subject of "Designing for Steel Castings." Using for illustration examples of steel casting that had been improperly designed and then redesigned to meet foundry requirements, he showed how hot tears, shrinkage cracks, gas pockets and numerous other possible troubles are entirely absent when the casting has been designed properly.

Other papers containing much information of interest and value to designing engineers included "Specifications for Steel Casting," by E. W. Campion; "Hardenability of Cast Iron" by D. W. Murphy and W. P. Wood; "Wear Testing" by P. S. Lane; and "Titanium in Cast Iron" by E. R. Starkweather.

Designing engineers found much of interest in the new design features seen in the many exhibits at the Milwaukee Auditorium. Exhibits of molding machines showed the continued trend to easier and more automatic operation. A number of these machines were equipped with devices to automatically give the number of jolts desired. Milwaukee Foundry Equipment Company uses a "jolt meter valve," which is essentially a hydraulic cylinder with an adjustable needle valve to regulate the speed with which the hydraulic piston travels, the rod of the piston tripping the jolt control valve. Adjusting the needle valve by means of a knurled thumb nut sets the machine for the desired number of jolts. Herman Pneumatic Machine Company showed a machine wherein an electric timer and an electric valve control the number of jolt strokes. The timer can be set anywhere between 1 sec. and 40 min.

Anti-friction bearings, in improved sealed housings are coming into more general use. An interesting application is in the "float arm" of arm type models of Milwaukee squeezers. The arm must be swung manually, hence the desire for anti-friction bearings. But in the working position the arm gets the full force of the squeeze pressure applied to the mold. In order to prevent this force from being transmitted to the arm bearings, where it would be greatly multiplied by the leverage, the arm locks into the frame when it is swung into working position.

Two floor type grinders on exhibit reflected the attention being given to fool-proof safety features in conjunction with maximum speed of operation. In both designs at swivel mounted guards over the grinding wheels are interlocked mechanically with the speed change control linkage, and the position of the guard determines the maximum speed at which the grinding wheel can be run. Thus, when the wheel is at its maximum diameter, with the hood over it in its highest position, the control must be set at lowest speed and cannot be changed. As the wheel wears to smaller diameter, making higher r.p.m. permissible, the hood or guard over the wheel can be lowered, thereby permitting the speed control to be set for a higher speed. Thus, in the grinder of the United States Electric Tool Company, the wheel driving motor is swivel mounted. Drive is from the motor pinion to one of 4 stepped diameter gears on the wheel shaft. In shifting the speed control lever, the motor is swiveled to take the pinion out of mesh, slid axially to another gear for speed change and swiveled back to bring pinion into mesh. All of this is accomplished by simply moving a control lever from one position to next, provided speed increase is not prevented by the hood interlock.

In the Safety Grinding Wheel and Machine Company grinder the motor is in a fixed position and the drive is through two steps of multiple V-belts running on variable pitch diameter sheaves; drive is from motor pulley to jack shaft, jack shaft to wheel shaft.

A hack saw exhibited by Armstrong-Blum Manufacturing Company has a hydraulic feed with rapid traverse. Machine has a capacity up to 18x18 in.; claimed to be the world's largest.

Among the other displays that attracted a great deal of attention were machines for cleaning castings, one exhibited by American Foundry Equipment Company and one by Pangborn Corporation. Both operated on the principle of an abrasive or shot being thrown out by a centrifugal wheel at a high velocity and impinging on the castings being cleaned, which are tumbled about in a drum. Jeffrey Manufacturing Company's and Allis Manufacturing Company's displays of feeders that conveyed the material by vibration of the conveyor produced magnetically, and magnetically driven screens attracted interested audiences, as did the exhibit of the Mathews Conveyor Company.

S.P.E.E. Meeting At Cambridge

IMMEDIATELY preceding the annual meeting of the Society for the Promotion of Engineering Education, which will be held from June 29 to July 2 at the Massachusetts Institute of Technology and Harvard University, the Mechanical Engineering Division of this society will hold a two-day conference at M. I. T. in Cambridge, Mass. At this conference, June 28-29, many of the professors of mechanical engineering, representing most of the leading institutions in this country, will gather to consider the various phases of teaching methods.

At the middle-atlantic states regional meeting held by this society last June at Columbia University, the major topic

under discussion was the question of the amount of "humanistic" studies that might well be included in an engineering course. On the other hand there is another school of thought that feels that more advanced engineering subjects should be included in engineering curricula. Both could be accomplished if it were not for the time element. It will be of interest to all engineers to know the general opinion that might be expressed at this meeting as to whether mechanical engineering courses should be broadened to include more non-technical subjects or whether more advanced technical subjects should be included.

Professor Frank L. Eidmann of the mechanical engineering department of Columbia University is chairman of the Mechanical Division of the Society.

Designers Honored by Franklin Institute

FOUR DESIGNING engineers were included among the fifteen engineers and scientists who received the 1937 Medal Awards of the Franklin Institute of Pennsylvania on Wednesday, May 19. These honors are conferred annually for scientific ingenuity and skill and for invention and discovery.

In consideration of the invention and development "of the Transitorq, a practical and useful variable- speed transmission unit," Mr. Richard T. Erban, consulting engineer of New York City, was awarded the Edward Longstreth Medal.

In consideration of "the adaptation of the constant-speed Fottinger type hydraulic coupling to the variable-speed requirements of industrial applications," Harold Sinclair, director of the Hydraulic Coupling & Engineering Company, Ltd., Middlesex, England, was also awarded the Edward Longstreth Medal.

The third recipient of the Longstreth Medal was Herbert L. Whittemore, chief of the engineering mechanics section of the National Bureau of Standards, "in consideration of his part in the invention and development of the Proving Ring for the direct checking of calibrations of testing machines."

The George R. Henderson Medal, founded in 1924 by Mrs. Virginia P. C. Henderson, to be awarded for meritorious inventions or discoveries in the field of railway engineering, was awarded to Dr. Rupen Eksergian of the Edward G. Budd Manufacturing Company, Philadelphia, Pa., "in consideration of his contributions to railway engineering and his accomplishments in the field of railway locomotive and car design." Dr. Eksergian is well known for his accomplishments in the design of the famous Zephyrs and other stainless steel streamlined trains.

Design Improvements Reduce Wear in Looms

AMONG the six papers delivered at the Symposium on Wear of Metals, held in Philadelphia on April 5 under the auspices of the Philadelphia District Committee of the American Society for Testing Materials, one by Albert Palmer of the Crompton and Knowles Loom Works told in detail how wear was reduced through improved design.

As pointed out by Mr. Palmer, wear is produced as a result of sliding, rolling and impact introduced not only through normal machine operation but also through vibrations resulting from that operation. From the standpoint of mechanical design wear can be reduced by increasing bearing areas, providing more accurate assemblies, improving the running fits of parts, providing locking devices to eliminate maladjustment resulting from vibration, reducing shock loads and making provisions for better lubrication.

Machine finish has a direct bearing upon wear. Parts assembled more securely and accurately, with finished surfaces at the points where relative motion takes place, will have a considerably decreased rate of wear. This has been clearly demonstrated in a comparison of two textile machines wherein more than 90 per cent of the material in the older design was cast iron with relatively little machining done on it. In the design of a comparable modern machine, total weight was increased 12 per cent, more than twice as much steel is used, and 40 per cent more machine work is required, much of it grinding and reaming.

In the modern design of looms, for example, machined pads are provided on the loomsides for all parts attached to it and bearings are supported in bored and reamed seats. In the older design the loomside was merely a rough casting to which the bearing boxes were fitted by hand. Also in the modern design the motor supporting frame is carried entirely by the loomside, and is not dependent upon a support to the floor. All of these improvements contributed greatly to a more rigid basic structure and the minimizing of vibrations.

The older machines had bored and reamed holes in grey iron castings to serve as shaft bearings that had to be line reamed on the assembly floor and given large clearances to compensate for the inaccuracies of hand fitting rough castings. Bearings in modern textile machines have clearances ranging from 0.0015 in. to 0.005 in., increased bearing areas, improved finish and better provisions for lubrication.

Ball and roller bearings with cold drawn centerless ground steel shafting and adequate provisions for lubrication are used in the modern loom, a refinement of design that over a period of almost seven years of operation has shown remarkable results in wear reduction over previous designs.

With reference to wear arising from oscillation combined with impact, the author showed how the crank connector that drives the reciprocating lay mechanism was improved to reduce wear and breakage. The old connector consisted of a wooden member with steel straps that went around the crank wrist at one end and the connector pin at the other. In the modern design a solid cast bronze bearing is used at the wrist end and a similar split bearing at the other end. The connector member consists of two steel rods with the connector pin bearing backed up by helical springs to cushion the shock when the lay mechanism is brought to a sudden stop.

Other design features for increased wear life described by Mr. Palmer include the use of chilled cast iron and heat-treated steel for rolls subject to the wear of rotation, rolling and impact, and the use of alloy cast irons. As a further means to reduce wear, the specification of the various lubricants that are required for looms are established by laboratory tests and the customers are supplied with these specifications together with the trade names of the products of lubricant manufacturers that meet these specifications.

The other papers that were presented at the symposium are: "General Discussion and Considerations Involved in Wear Testing, Including the Classification of the Various Types of Wear." H. W. Gillett, metallurgist, Battelle Memorial Institute; "Some Important Variables Encountered in Wear Tests on Cast Iron," D. E. Ackerman, metallurgist, research laboratory, The International Nickel Co.; "Wear of Metals from the Railroad Viewpoint," L. W. Wallace, director, equipment research division, Association of American Railroads; "Wear from the Automotive Viewpoint," W. E. Jominy, metallurgical

department, research laboratories section, General Motors Corp.; "Wear from the Power Equipment Viewpoint," N. L. Mochel, metallurgical engineer, Westinghouse Electric and Manufacturing Company.

NEMA Publishes Three New Standards

NEW POWER Switchboard Standards, Oil Circuit Breaker Standards, and Attachment Plug Standards have just been published and released by the National Electrical Manufacturers Association.

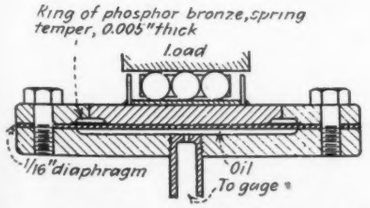
All information available on the manufacture, test and performance of oil circuit breakers and power switchboards is given in these two standards, which supersede the N.E.M.A. Switchgear Standards released in 1931. The attachment plug standards cover the manufacture and test of attachment plug caps, bodies and receptacles.

Copies of the publications may be obtained from the National Electrical Manufacturers Association, 155 East 44th Street, New York, N. Y. Prices are: NEMA Power Switchboard Standards $1.10 a copy, NEMA Oil Circuit Breaker Standards 90 cents, and NEMA Attachment Plug Standards 25 cents.

Hydraulic Device Determines Loads

MUCH ATTENTION has been given in the design of agricultural implements to methods for determining the loads imposed on the tillage tools. In a paper presented before the Power and Machinery Division of the American Society of Agricultural Engineers, A. W. Clyde of Penn State College describes a hydraulic device for measuring the loads on moldboard and disk plows and disk harrows. The information obtained through this device is used to determine the proper pitching of the tool, its design for strength and rigidity and the relative merits of various shapes of tools.

The design of the hydraulic pressure cell for determining the forces is shown in the accompanying design. Its method of operation is evident. As described by Mr. Clyde, a number of these cells are placed at various convenient points where they will measure the forces exerted on the tillage tool. The gage records the unit oil pressure or the dial may be graduated to read the total load in pounds.



Latest design of hydraulic pressure cell for measuring forces on tillage tools

This hydraulic cell and its applications is only one of the numerous developments in the engineering of agricultural machinery. Results from full scale testing equipment are being used to check theoretical analyses and laboratory results; scientific study is putting empirical design on its last legs.

Meetings

AMERICAN SOCIETY FOR TESTING MATERIALS—*Annual meeting, Waldorf-Astoria Hotel, New York, N. Y. June 28-July 2. C. L. Warwick, secretary, 260 S. Broad St., Philadelphia, Pa.*

ASSOCIATION OF AMERICAN RAILROADS, MECHANICAL DIVISION—*Annual meeting, Municipal Auditorium, Atlantic City, June 16-23.*

ECONOMICS CONFERENCE FOR ENGINEERS — *Seventh annual convention, Stevens Engineering Camp, Johnsonburg, Warren County, N. J. June 18-26. Harvey N. Davis, Stevens Institute of Technology, Hoboken, N. J.*

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS—*Summer convention, Milwaukee, Wis. June 21-25. H. H. Henline, secretary, 33 West 39th St., New York, N. Y.*

Special Features at A.S.T.M. Meeting

THROUGHOUT the week of June 28–July 2, the American Society for Testing Materials will hold its 40th annual meeting at the Waldorf-Astoria Hotel in New York City. Simultaneously and in conjunction with the A.S.T.M. meeting there will also be in progress the fourth exhibit of testing apparatus and related equipment.

Technical papers will be presented at more than twenty formal sessions, some of which will be devoted entirely to symposiums comprising several groups of papers. Of special interest to designing engineers will be the session wherein four papers on various topics relating to cast iron will be presented. These topics will include the correlation between the physical properties of cast iron with the thickness of the casting and a study of the effect of length of span on the transverse test results for cast iron.

Most of the society's standing committees will present reports on the results of their standardization and research work during the current year and it is expected that a number of committees will have papers appended to the reports dealing with particular problems of interest to the committee.

More than 40 companies will exhibit laboratory and testing machines and instruments, in addition to which there will be exhibits sponsored by several of the A.S.T.M. committees. These special displays will include photomicrographs, radiographs and X-ray photographs.

Welding Society Appoints Managing Director

AS A PART of the program adopted by the Board of Directors of the American Welding Society at the annual meeting in Cleveland, Ohio, last October, Mr. Warner S. Hays has been appointed as managing director. Through this new program adopted by the society it is expected that both the membership and the welding industry will be served better, it being anticipated that within the coming year the total membership of the society will be increased 100 per cent.

Do You Know That—

CLOCK HANDS manufactured for the Warren Telechron Company of Ashland, Mass., by the J. H. Winn's Sons of Winchester during 1936 required 5 tons of steel and 2 tons of brass. To lighten the burden on the large clock motors the hour and minute hands are made of aluminum and the second hands are made of duralumin. To guard against rust, steel hands are lacquered top and bottom and must be wrapped individually before shipment. (51)

HYDROGEN, when used as a circulating medium in large generators, reduces windage losses to 10 per cent of what they would be with air, and this results in an improvement in the efficiency of the generators of from 0.6 to 1.1 per cent, depending on the size and r.p.m. of the units. Hydrogen requires considerably less pressure to circulate the necessary volume, and it has many times the thermal conductivity of air. (52)

(For details, write the editor, giving the item number.)

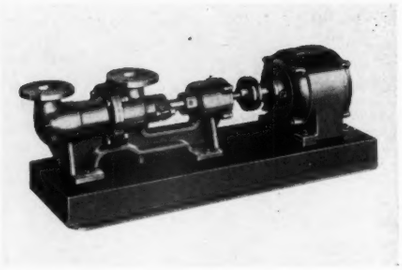
New Materials and Parts

Miniature Instruments

Entire line, in a variety of forms for industrial and radio applications, employs only two mechanisms, contributing to interchangeability of parts. Mechanisms are of improved design having higher torque-weight ratios and low volt-ampere burdens. Round and rectangular designs available in alternating current, direct current, copper-oxide rectifier, and radio frequency types. For use as ammeters, milliammeters, microammeters, voltmeters, millivoltmeters, power-level meters and volt-ohmmeters. Capacities as low as 20 microamperes available in moving-coil types. Self-contained ammeters of 50 amperes and voltmeters of 200 volts, and portable housings for use with round-type instruments are obtainable. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Moineau Pump

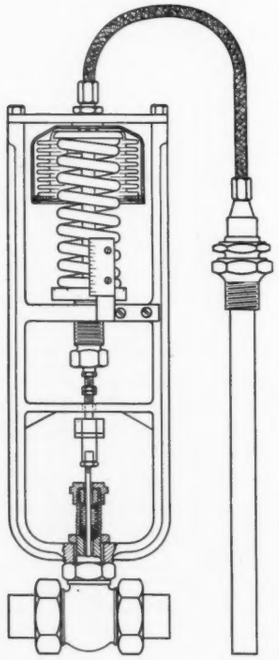
Valveless, positive-displacement unit with a single rotating assembly. A spiraled and eccentric rotor rolls in a helical stator as a bearing, maintaining a sealed-surface contact throughout its length and thus effecting positive displacement from one end of stator to other. Flow is uniform, and rotor seals against forward or backward flow of liquid being pumped. Claimed to be unchokable and capable of handling from 25 to 35 per cent solids suspended in liquid. Self-priming down to 1½ in. of mercury pressure. Overall efficiencies in larger sizes are as high as 65 per cent, and range of discharge pressures over which efficiency



remains high is wide. Maximum pressures limited only by allowable physical stresses. Five sizes are being placed in production. Robbins & Myers, Inc., Springfield, Ohio.

Temperature Controllers

Improved line of "self-operating" temperature controllers features a new design of flexible seamless metal bellows and several refinements of design, material and workmanship. Suitable for industrial applications where close



control obtainable with auxiliary power is not necessary or where steam pressure available is less than 10 lb. per sq.in. Temperature ranges are approximately 75 deg. between the limits of 30 and 450 F. Valves are semi-balanced, in sizes from ½ to 2 in. C. J. Tagliabue Mfg. Co., Brooklyn, N. Y.

Colored Molding Powders

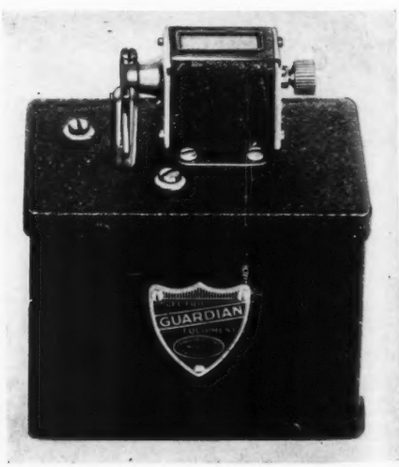
In all colors, for injection and compression molding. Reported to flow easily under heat and pressure and set quickly in mold, thereby resulting in faster molding cycle. Of the cellulose-acetate type, the powders are offered in five grades ranging from extra hard compound used to produce well defined mottlings to a more flexible type of plastic used for the production of thick-walled or heavy parts. Masuron Div., John W. Masury & Son, Brooklyn, N. Y.

Crimped Metals in Coils

Pre-crimped and prefinished for use as trim, decoration, panelling, table edges, displays, electrical devices, toys and novelties. Available in four metals, steel, zinc, brass and copper; four finishes, nickel, chrome, brass and copper; three patterns, vertical, horizontal and square crimps; from ¼ to 12 in. wide for feeding to automatic machines. American Nickeloid Co., Peru, Ill.

Remote Counter

Solenoid operated, capable of handling up to 400 impulses per min. without overheating or sticking, even when



in continuous operation. Operating mechanism is inclosed in a black crackle-finish case for protection against dust and dirt. Available with 5 figure, Veeder-Root counters, either reset or non-reset. For operation at 6 to 110 volts d. c. and 24 to 220 volts a. c.—Guardian Electric Mfg. Co., 1621–27 W. Walnut St., Chicago, Ill.

Air Compressors

Made in ¼ and ½ hp. sizes with automatic start and stop control and equipped with a new seamless steel tank and an improved check valve. For single-phase current they are equipped with

a brushless capacitor-type motor and a built-in automatic protection switch giving overload and under-voltage protection. Rated for 150 lb. per sq. in. maximum pressure. May be set for lower pressures. The ¼ and ½ hp. units are available on a 2.4 cu.ft. tank as illustrated. The ½ hp. size is also available on a 4.6 cu. ft. tank in either vertical or horizontal mounting. Units are furnished with or without the tank. Ingersoll-Rand Co., Phillipsburg, N. J.

Asbestos Sheet Packing

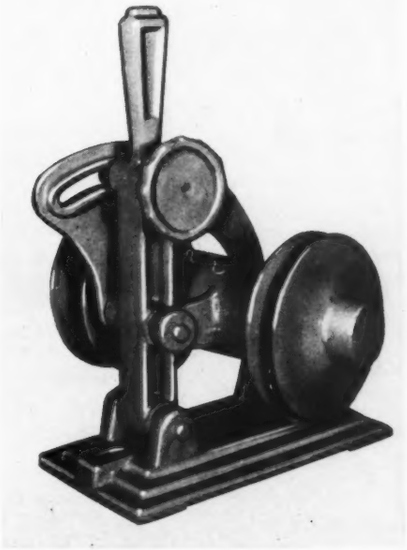
A sulphur-free, neoprene-bonded, compressed asbestos sheet packing, known as Prenite 20M, offering increased resistance to oil as well as to such refrigerants as Freon, methyl-chloride and sulphur-dioxide. Absence of sulphurs in its composition makes for a packing that will not corrode metal parts. Available in 50x50 in. sheets in 1/64, 1/32, and 1/16 in. thicknesses. Mechanical Rubber Goods Div., The B. F. Goodrich Co., Akron, Ohio.

Low P. F. Loss Plastic

For use on high-frequency radio and electrical apparatus. Known as Durez 1601, it has power factor (A.S.T.M.) of 0.34 per cent, claimed to be lower than that of any material of its type. It is also said to possess excellent molding qualities which permit its use for a variety of applications, such as in x-ray machines, diathermy apparatus, high-frequency measuring and research equipment, and short-wave radio parts. General Plastics, Inc., North Tonawanda, N. Y.

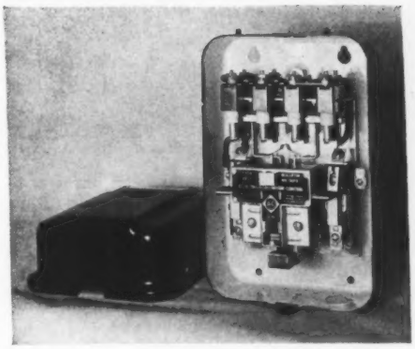
"HI-EFF" Vari-Speed Control

Incorporates the adjustable V-belt pulley principle in a single shaft design. Consists of a single shaft on which are two adjustable V-belt pulleys which vary in diameter as their distances from the driving and driven pulleys are changed. It offers infinite speed selectivity within ratios of 5 to 1 and tests show it to be over 90 per cent efficient. Available in sizes from ¼ to 7½ hp. Columbia Vari-Speed Co., Wheaton, Ill.



Air Motor-Starter

Type AP-7 across-the-line air motor-starter equipped with "Ruptors" or inclosing chambers which confine and depotentiate the arc formed by circuit interruption. These arc-depotentiating chambers increase the interrupting ability of the contacts and form an isolating barrier between contacts of opposite polarity. Other features include vertical make-and-break, inclosed temperature overload relays, unit construction, large silver double break contacts, contacts accessible and quickly renewable, pilot circuit isolated from motor circuit permitting a separate control voltage for push-button circuit, motor starter unit arranged for flat surface mounting when applied without inclosure. Furnished for 7½ hp. at 440 and 550 volts, 5 hp. at 220 volts and 3 hp. at 110 volts. Allis-Chalmers Mfg. Co., Milwaukee, Wis.



Graphitic Steel

New alloy steel containing included graphite. For application in the tool and die industry. Claimed to possess the free machining qualities of cast iron combined with the high strength and response to heat-treatment of steel. Produced under tradename "Graph-sil" for water hardening uses and "Graph-mo" for oil hardening uses. Both grades are suitable for dies used in cold working and shaping steel, brass, Dowmetal, aluminum, paper and bronze.—Steel & Tube Div., The Timken Roller Bearing Co., Canton, Ohio.

Electrode for Fillet Welding

Designated as "Fleetweld 8," developed for maximum speed and economy in the production of high quality fillet and lap welds, this new electrode eliminates the necessity of multiple pass welding and permits the production of such welds without undercutting or overlap. Fillet welds up to ⅜ in. with one plate vertical can be produced in one pass. The welds show no undercutting at the vertical plate and no overlap at the horizontal plate. The electrode is heavily coated for welding by the shielded arc process. The welds produced are smooth and dense with notably high physical properties. "Fleetweld 8" is

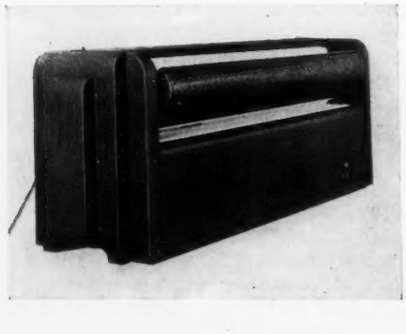
available in 14 in. and 18 in. lengths, the 14 in. lengths made in 3/8, 5/16, 1/4, 3/16 and 5/32 in. sizes and the 18 in. lengths are made in 3/8, 5/16 and 1/4 in. sizes. The Lincoln Electric Co., Cleveland, Ohio.

Any Angle Dial Thermometer

Providing an easier means of reading temperatures by simply tilting the dial to the angle of greatest visibility. Is claimed to be practically indestructible. The temperature system is entirely of steel with all joints welded. Its molded plastic condensate case is moisture and fume proof and will indefinitely retain its black finish. May be substituted for glass thermometers and will fit any glass thermometer socket. American Schaeffer & Budenberg Div., Consolidated Ashcroft Hancock Co., Inc., Bridgeport, Conn.

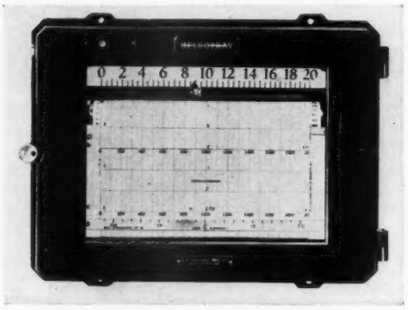
Low-Cost Continuous Printer

For exposing black-line paper or blueprint paper of any width up to 42 in. Model 3 BW printer is built for 100 volts a.c. and 110 volts d.c. Plugs into any light socket and consumes less current than the usual arc lamp machines. When used in conjunction with the Bruning black and white developing machine prints from tracings or drawings can be developed instantaneously and are ready for immediate use. The prints need no washing or drying. It is claimed that a single operator, using the printer with average tracings on cloth, can print and develop two to three 50-yard rolls of black-line paper per day. Chas. Bruning Co., Inc., 102 Reade St., New York, N. Y.



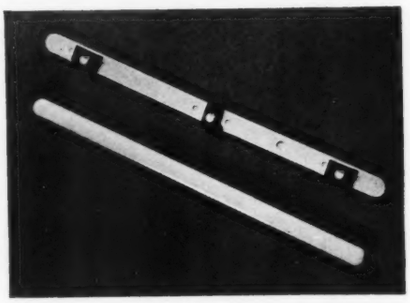
Multipoint Temperature Recorder

A high-speed photoelectrically balanced recorder, called the Celectray, the primary controlling element of which is a sensitive mirror galvanometer in which an inertialess beam of light takes the place of the customary metal boom or pointer. The beam of light in moving on and off a phototube passes the controlling edge of a screen thus operating relays which in turn control a reversible motor driving the moving contact of a potentiometer or bridge. The phototube is not a calibrated element and furnishes trigger action only. Thus the instrument is photoelectrically balanced when the moving light-beam is accurately split by the controlling edge. As many as 12 records can be obtained simultaneously. The average speed of the multiple point recorder is less than 15 sec. per point and it is claimed to be accurate to 0.1 per cent. C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.



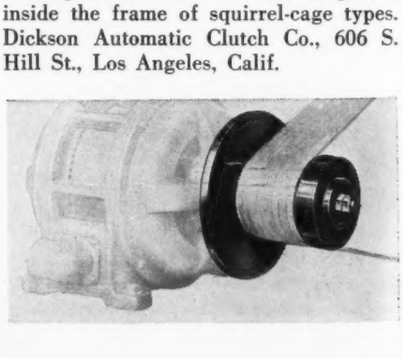
Detachable Molded Strips

Decorative strip consisting of a piece of Plaskon in any desired color and measuring 8 in. in length by 7/16 in. in width. On the back are three 1/4 in. long projections which fit into the piece to be decorated, to which it is attached by means of Tinnerman speed nuts. The speed nut is a small piece of steel with two teeth so cut as to slide easily over the end of the projection and to cling there tightly and firmly. The fastening is extremely strong, yet the nut can readily be removed by giving it a half turn, which disengages the teeth. Designed for decorative effects on ranges, radio cabinets, boxes, and any similar large surfaces which can be relieved by contrasting decoration. Tinnerman Stove & Range Co., Cleveland, Ohio.



Adjustable Automatic Clutch

Consists of a drive plate keyed to the drive shaft; a movable plate, upon the hub of which is keyed a pulley, sheave or sprocket, the whole assembly being mounted on a quill; and, floating on the shaft, an actuating unit equipped with a time-lag adjusting mechanism and containing centrifugal weights which operate the movable clutch plate as the actuating unit comes up to speed. Will operate equally efficiently in either direction of rotation. A simple adjustment regulates the time-lag period. The adjustable time-lag permits the motor to attain full speed before the load is applied. It applies the load gradually, thereby avoiding damage from sudden shocks in starting. It does away with the necessity for high starting-torque motors and in many cases permits the substitution of squirrel-cage motors for more expensive slip-ring motors. It is claimed that it allows overload relays to be set as close as 5 per cent to running loads without danger of power cut-offs when starting. It is non-locking, releasing at once when the speed drops below the critical point. Sizes range from 1/20th hp. to 350 hp. and for speeds from 600 to 3,600 r.p.m. Time-lag interval is adjustable, downward from the maximum, which may be as much as 10 min. Under special conditions it can be installed on the high-speed shaft of most gear-motor and variable-speed units and can also be placed inside the frame of squirrel-cage types. Dickson Automatic Clutch Co., 606 S. Hill St., Los Angeles, Calif.



Manufacturers' Publications

ANCHORAGE DEVICES—The Rawlplug Co., Inc., 98 Lafayette St., New York, N. Y. Booklet No. 37, 32 pages, 3½x6¼ in. Information on the anchoring of bolts or screws in solid materials of any description. Advantages of various types of anchors and data for their proper selection and installation are included.

BALL BEARINGS—Nice Ball Bearing Co., Nicetown, Philadelphia, Pa. Catalog No. 102, 65 pages, 4¼x7¼ in. Data, drawings and specifications covering the products of the company including their Red Diamond casters, the new ground precision radial bearings, unground radial and combination bearings, thrust bearings, retainers and ball bearing wheels. Catalog 100 is devoted entirely to data on their Red Diamond ball bearing casters.

BEARINGS—Johnson Bronze Co., New Castle, Pa. Bulletin EM-7, 40 pages, 8½x11 in. Alphabetical listing of electric motor bearings with illustrations, descriptions and specifications. A section is devoted to hexagon bars and solid and cored bronze bars.

BELT LACING—The Bristol Co., Waterbury, Conn. Bulletin No. 725, 3½x6¼ in. Information concerning the use of various types of steel belt lacing, with sizes and price lists.

CHAIN CONVEYORS — Baldwin-Duckworth Chain Corp., Springfield, Mass. Booklet, Dossier A-1, 14 pages, 9¼x11 in. Data on conveying equipment for high temperatures. Based on the Crime File Dossier type of detective story.

CONTROLLERS—C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y. Catalog No. 900C, 32 pages, 8½x11 in. A well-illustrated catalog describing automatic, non-indicating controllers for temperature, pressure and time.

COUPLINGS—T. B. Wood's Sons Co., 1200 Fifth Ave., Chambersburg, Pa. 2-page supplement to Catalog No. 70, 6x8¾ in. Illustrating and describing universal giant, type E, flexible coupling.

CURRENT-INPUT CONTROLLER — Automatic Temperature Control Co., Philadelphia, Pa. Bulletin G-12, 6 pages, 8½x11 in. Additional information on the current-input controller for furnaces, ovens, platens and other electrically-operated units with wiring diagrams and ratings.

ELECTRICAL APPARATUS — Janette Mfg. Co., 556-558W. Monroe St., Chicago, Ill. Bulletin 226, 3½x6¼ in. Illustrates products of the company including motors, generators, motor generator sets, hydrolators, motorized speed reducers, motorized blowers, gasoline electric plants, etc.

ELECTRICAL CONTROL EQUIPMENT—Struthers Dunn, Inc., 139 N. Juniper St., Philadelphia, Pa. Folder 3½x6 in. Illustrating a number of their timing devices, relays, thermostats, electric counters, melting pots, ladles, etc.

FEED CONTROL PANEL—Vickers, Inc., 1400 Oakman Blvd., Detroit, Mich. Bulletin 36-10, 8½x11 in. Describes series C2-1237 feed control panel for hydraulic circuits with which remote electric control may be used advantageously.

LOCALIZED LIGHTING — The Fostoria Pressed Steel Corp., Fostoria, Ohio. Catalog, 14 pages, 8½x11 in. Describing various styles of flexible "Localite" lamps for attaching directly to machines to be used in industrial plants where increased illumination is required for close accurate work.

LUBRICATION—Bijur Lubricating Corp., Long Island City, N. Y. Bulletin "D," 15 pages, 8½x11 in. Defines the field of application of centralized, forced feed, automatic lubrication systems. The Bijur meter-unit is described in detail and numerous representative machines carrying Bijur equipment are illustrated.

LUBRICATION—Shell Petroleum Corp., St. Louis, Missouri. Vol. I, Nos. 1, 2 and 3, 25 pages each, 8½x11 in. Non-technical information regarding the manufacture and application of lubricants is presented in the first three booklets of a series entitled "Panorama of Lubrication."

LUBRICATION—Stewart-Warner Corp., 1826 Diversey Parkway, Chicago, Ill. 20 pages, 8½x11 in. A revised edition of the "Alemite Industrial Lubrication Manual." Besides listing industrial lubricants, data are given on where and when specific lubricants should be used.

MAGNETIC BRAKE—Stearns Magnetic Mfg. Co., Milwaukee, Wis. Bulletin No. 600, 7 pages, 8½x11 in. Describing new style "DM" magnetically-operated brake which operates either floor or motor mounted through a keyed shaft, geared directly to the operating elements of the brakes.

MAGNETIC RELAYS—Ward Leonard Electric Co., Mount Vernon, N. Y. Bulletin 81, 8 pages, 8x10½ in. Lists more than 100 relays for intermediate duty (10-15 amp.) on d.c. and a.c. circuits for two and three wire control. Includes coil and contact data, contact arrangements, inclosures and illustrates relays assembled from standard parts for use on special applications.

MATERIAL SAMPLE FOLDER—Felt Products Mfg. Co., 1504 Carroll Ave., Chicago, Ill. Folder, 4x9 in. Contains samples of felt, cork, asbestos, fiber and rubber products with descriptive notes.

MECHANICAL PACKINGS — United States Rubber Products, Inc., 1790 Broadway, New York, N. Y. Catalog No. 101, 112 pages, 8¾x11¼ in. A well-illustrated reference guide on packings for various applications, presenting in condensed form engineering data, specifications and recommended uses for each type of packing.

METALGRAM—Apex Smelting Co., 2554 Fillmore St., Chicago, Ill. Data Sheet No. 19, 4 pages, 8½x11 in. Graphic charts showing elongation of zinc base die-cast alloy No. 6 when cast under controlled variables.

METAL SPRAYING—Condenser Service & Engineering Co., Inc., 310 Twelfth St., Hoboken, N. J. 8 pages, 8½x11 in. Discusses and illustrates by practical applications in various industries the advantages and economies of sprayed molten metal.

MICROMAX CO_2 RECORDING EQUIPMENT—Leeds & Northrup Co., 4902 Stenton Ave., Philadelphia, Pa. Catalog N-91-163, 12 pages, 7¾x10½ in. Describes Micromax CO_2 recording equipment with saturated-gas cell assembly.

MIDGET CONTACTORS AND LINESTARTERS—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Leaflet 20568-A, 8¼x10¾ in. Covers Class 11-220 line of reversing and non-reversing midget contactors and linestarters.

"MOLDERS OF PLASTICS"—American Insulator Corp., New Freedom, Pa. Loose-leaf booklet, 48 pages, 9x12 in. General information on the principal molding materials, their characteristics, physical and chemical properties, applications and limitations. A section of the booklet lists plastic parts available from stock molds of the company, attractively presented by means of blueprint drawings and photographs.

MOTOR-GENERATOR SETS—Reliance Electric & Engineering Co., Ivanhoe Rd., Cleveland, Ohio. Bulletin 501, 4 pages 8½x11 in. Illustrations and brief descriptions of various types of motor-generator sets.

OXIDATION—Steel & Tube Div., The Timken Roller Bearing Co., Canton, Ohio. Technical Bulletin No. 10, 4 pages, 8½x11 in. Data on comparative oxidation resistance of 13 types of alloy steels at elevated temperatures.

OIL SEALS—The Chicago Rawhide Mfg. Co., 1301 Elston Ave., Chicago, Ill. Booklet, 24 pages, 8½x11 in. Descriptive data, tables of sizes and price lists on the "Perfect" oil retainer for bearing protection. Numerous pictures and drawings illustrating typical applications are included.

PNEUMATIC PRODUCTS AND FITTINGS—C. A. Norgren Co., Inc., Denver, Colo. Catalog No. 200, 24 pages, 8½x11 in. Presenting a line of regulating, reducing and relief valves, lubricators, strainers, hose and fittings for use with air and gas.

PRESSURE RECORDER AND CONTROLLER—The Bristol Co., Waterbury, Conn. Bulletin No. 483, 8 pages, 8x10½ in. Description and applications of low-range draft and pressure recorders and controllers.

PUSHING, PULLING AND LIFTING CYLINDERS—Hanna Engineering Works, 1765 Elston Ave., Chicago, Ill. Catalog No. 224, 20 pages, 8½x11 in. Showing construction details, dimensions, and types of actuating cylinders, includes description of operating valves.

"SELLING POINTS FOR HOUSEHOLD APPLIANCES"—Porcelain Enamel Institute, Inc., 612 N. Michigan Ave., Chicago, Ill. Booklet, 24 pages, 8½x11 in. An interesting reproduction of a series of advertisements of the Institute. Also illustrates various porcelain enameled products.

SHIELD-ARC WELDER—The Lincoln Electric Co., Cleveland, Ohio. Bulletin No. 317, 4 pages, 8½x11 in. Contains a description of the design, control features, construction and dimensions of the Lincoln S.A.E. welder.

SINGLE PHASE MOTORS—Century Electric Co., St. Louis, Mo. Bulletin No. 1,000, 8 pages, 8x10½ in. Illustrating and describing the construction and characteristics of brush lifting types of single phase motors.

SPEED INDICATORS—Hasler-Tel Co., 461 Eighth Ave., New York, N.Y. Folder, 8½x11 in. Data on speed indicating devices for registering high and low speeds.

STEP-TAPERED TUBES—Summerill Tubing Co., Bridgeport, Pa. Leaflet, 8½x11 in. Drawings of typical step-tapered sections showing how both the diameter of tube and wall thickness can be reduced. Developed for application in aircraft design.

TESTING AND MEASURING INSTRUMENTS—James G. Biddle Co., 1211-13 Arch St., Philadelphia, Pa. Bulletin No. 1490, 12 pages, 7¾x10½ in. Covering their line of "Megger" instruments for continuous and semi-continous duty.

THERMOMETERS—American Schaeffer & Budenberg Div., Consolidated Ashcroft Hancock Co., Inc., Bridgeport, Conn. Catalog 200, 48 pages, 8x11 in. Specific data and price lists on various indicating thermometers.

VIBRATION ELIMINATORS—Vibration Eliminator Co., 41-26 Thirty-Seventh St., Long Island City, N.Y. Bulletin, 18 pages, 4¾x7¼ in. "Stop Vibration" is the title of this booklet illustrating various installations of vibration eliminators under actual working conditions.

Z-METAL—Arcade Malleable Iron Co., Worcester, Mass. Bulletin, 15 pages, 8½x11 in. Describing physical characteristics of Z-metals and illustrating numerous castings made from it.

Z-METAL—Arcade Malleable Iron Co., Worcester, Mass. Slide Rule Chart, 5½x3¼ in. Comparing physical properties of cast metals and forged steel and also containing comparative descriptions and characteristics of Z-metal castings.

Books and Bulletins

Fluid Mechanics

RUSSEL A. DODGE AND MILTON J. THOMPSON. *495 pages, 6x9 in. Red clothboard covers. 267 illustrations, 12 tables. Published by the McGraw-Hill Book Co., Inc., 330 West 42d St., New York, N. Y. Price $4.00.*

The authors have compiled and presented in this excellent volume material for a course in the study of fluid motion that covers the statics and dynamics of gases and liquids.

Beginning with an exposition of the fundamentals of elementary hydraulics, the book advances methodically to an introduction to the principles governing the dynamics and thermodynamics of compressible and viscous fluids. Chapters deal with statics of fluids, flotation, dynamics of fluids, impulse and momentum, dynamic lift and propulsion; flow in pipes, through orifices and tubes; dynamic similarity and special problems in viscometry and laminar flow.

Many problems are contained in the text, each of which is designed to emphasize the application of a particular principle. References to publications are also included for the assistance of the reader who wishes to study the subject in greater detail.

Strength of Materials

ALFRED P. POORMAN. *314 pages, 6x9 in. 193 figures, 16 tables. Blue cloth binding. Published by the McGraw-Hill Book Co., Inc., 330 West 42d St., New York, N. Y. Price $3.00.*

Because of the great increase in the use of welding, the author has added to the third edition of this textbook articles on fillet-welded and butt-welded joints. An article on shearing stresses in non-circular shafts has been included for the first time, also the subjects of shear centers of channel sections, H-sections with unequal flanges and angle sections have been added.

In this edition, the deflection of beams has been treated in only two ways, by the double integration method and by the area moment method. The chapter on the equivalent cantilever method has been omitted. Most of the problems are new.

Written primarily to meet the needs of undergraduate students, the book deals with the theoretical elastic behavior of engineering materials concurrently with the results of experiment. The contents comprise chapters dealing with stresses and strains in tension, compression and shear of simple members; design of riveted and welded joints, torsion of shafts, stresses and deflections of various types of beams, combined stresses and column formulas. Throughout the book illustrative examples are solved to aid in developing methods for analyzing data presented and applying principles.

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Standards of Hydraulic Institute

SEVENTH EDITION. *Loose Leaf, 8½x11 in. Published by the Hydraulic Institute, 90 West St., New York, N. Y. Price* $1.

A new revised edition containing complete technical and engineering data on pump standards. The book is divided into seven sections: (1) general section, (2) centrifugal pumps, (3) rotary pumps, (4) reciprocating pumps, (5) deep well turbine pumps, (6) test codes (7) data section. Each section may be purchased separately.

Heat Transfer in Evaporation and Condensation

MAX JAKOB. *75 pages, 6x9 in. Engineering Experiment Station Reprint No. 10. Published by the University of Illinois, Urbana, Ill. Price 35 cents.*

Comprises six lectures relating to the problems of heat transfer, delivered by the author at various universities and before groups of engineers. The lectures are divided into two groups. The first group, including lectures one to three, is devoted to evaporation and the second group, including lectures four to six, covers condensation.

An Investigation of Relative Stresses in Solid Spur Gears

PAUL H. BLACK, *32 pages, 6x9 in., 16 illustrations, 6 tables. Paper covers. Bulletin No. 288, Engineering Experiment Station. Published by the University of Illinois, Urbana, Ill. Price 40 cents.*

A discussion of an investigation having for its objects the determination of: Stress concentration factors for spur gear teeth of the Brown and Sharpe form; the best location of keyway with respect to the teeth in a solid gear; and the maximum bore for a given solid gear.

Following a description of method and apparatus, the author describes the choice of material for and the preparation of models. The stresses indicated by the photoelastic method are compared with stresses calculated by the Lewis equation and also the combined load equation.

PRODUCT ENGINEERING + REFERENCE BOOK SHEET

Starting Torque of Split Phase Motors—I

Calculation of constants from winding data and machine dimensions

A. F. PUCHSTEIN and T. C. LLOYD

1. To calculate the leakage reactance of a single-phase induction motor with squirrel cage rotor three permeances will be needed, slot, zigzag and end connection. Differential permeance and effects of skew will be omitted.

(*a*) Slot leakage permeance. Slot constants, K_s for four common slot shapes are given in Fig. 1, allowance has been made for degree to which slot is filled with conductors, dimension *b* indicating the "fullness."

Stator slot leakage permeance $P_s' = 3.60\ LK_s'/S_1$

L = axial lgth. of core in in.,
K_s' = stator slot shape const.,
S_1 = number of stator slots.

Rotor slot leakage permeance $P_s'' = 3.60\ LK_s''/S_2$

K''_2 = rotor slot shape const.,
S_2 = number of rotor slots.

(*b*) Zigzag leakage permeance. First Method.

Stator zigzag permeance when $T'' = \leqq \lambda'$

$P_z'' = (3.19L/S_1)\ [(T'' - e')/6\delta]$
T'' = tooth face rotor in in.,

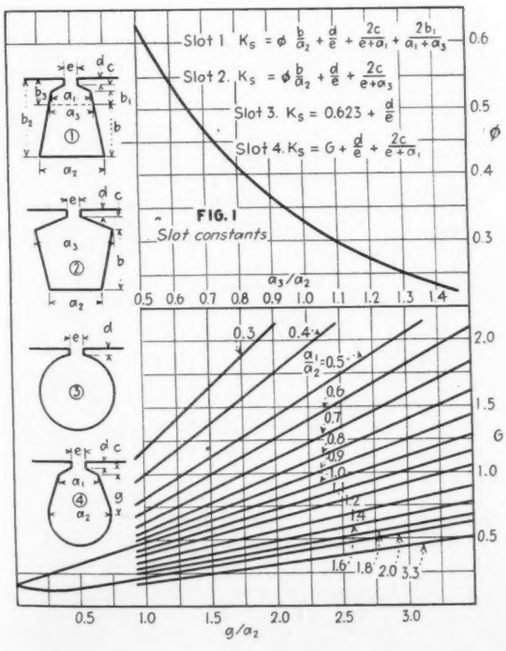
λ' = tooth pitch stator in in.,
e' = slot opening stator in in.,
λ = air gap lgth. (radial) in in.

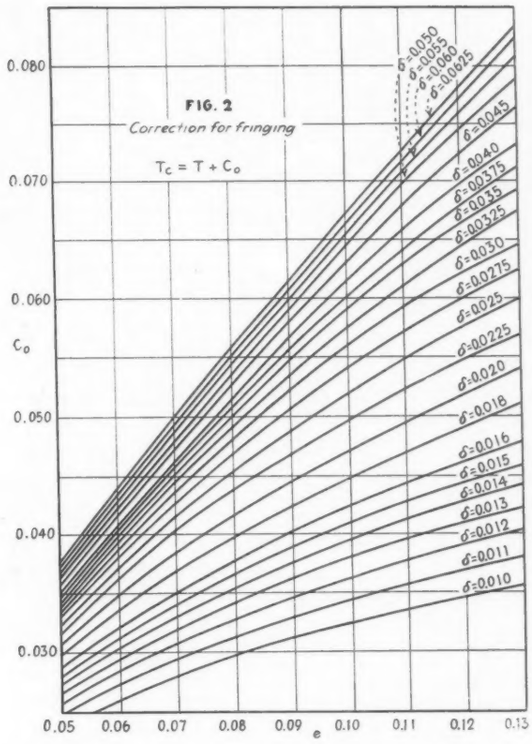
When $T''>\lambda'$, $P_z' = (3.19L/S_1)\ (T'/6\delta)$
T' = tooth face of stator in in.

Rotor zigzag permeance when $T'\leqq\lambda''$,

$P_z'' = (3.19L/S_2)\ [(T'-e')/6\delta]$
e'' = slot opening of rotor in in.

When $T'>\lambda''$, $P_z'' = (3.19L/S_2)\ (T''/6\delta)$
λ'' = tooth pitch of rotor in in.


Slot 1. $K_s = \phi\frac{b}{a_2} + \frac{d}{e} + \frac{2c}{e+a_1} + \frac{2b_1}{a_1+a_3}$
Slot 2. $K_s = \phi\frac{b}{a_2} + \frac{d}{e} + \frac{2c}{e+a_3}$
Slot 3. $K_s = 0.623 + \frac{d}{e}$
Slot 4. $K_s = G + \frac{d}{e} + \frac{2c}{e+a_1}$
FIG. 1
Slot constants
a_3/a_2
g/a_2
ϕ
G



Second method for obtaining zigzag permeance.

Combined stator and rotor zigzag permeance:

$$P_{zz} = \left(\frac{2.40}{S_1 + S_2}\right)\left(\frac{\lambda' + \lambda''}{\delta}\right)\left(\frac{T_c' + T_c''}{\lambda' + \lambda''} - 0.5\right)^2 L$$

T_c' = the corrected tooth face of the stator in in.
T_c'' = the corrected tooth face of the rotor in in.

Correction allows for fringing at the sides of teeth.

In any case $T_c = T + C_o$ (stator or rotor)

C_o = correction from Fig. 2, for gaps and slots.

(*c*) End Connection leakage permeance:

Combined stator and rotor: $P_e = \lambda K_e/2P$

λ = pole pitch in in., P = number of poles.
K_e = End ring rotor construction constant.

(*d*) Total leakage permeance P_T:

$P_T = P_s' + P_s'' + P_z' + P_z'' + P_e$

or $P_T = P_s' + P_s'' + P_{zz} + P_e$

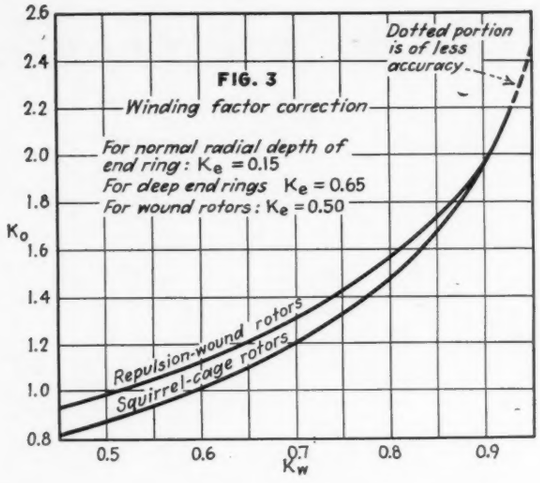
Choice of the two equations given above depends upon the method used for calculating the zigzag leakage permeance.

2. Correction for distribution, and calculation of leakage reactance.

Above values of leakage permeance must be modified by winding distribution factor k_w for concentric types of windings.

(*a*) Let the greatest number of conductors in any slot under a pole be unity, and a lesser number be represented by an appropriate decimal fraction. Winding distribution under a pole might then be (for example):

1.0–0.75–0.50–0–0–0–0.50–0.75–1.0



(*b*) Determine teeth enclosed by each coil.

(*c*) Calculate the half-tooth angle = 90 deg. ÷ slots per pole.

(*d*) Calculate half-coil span for each coil = teeth inclosed × half-tooth angle in deg.

(*e*) Obtain sine of half-coil span angle and multiply by "decimal fraction of coil." Repeat for each coil.

(*f*) Add the results of (*e*) and divide by the sum of the decimal fractions of coils under one pole. The result is k_w, a winding factor varying from 0.6 to 1.0.

The leakage permeance corrected for winding distribution is then $P_T K_o$; where K_o as plotted in Fig. 3 is a k_w function.

Total leakage reactance for stator and rotor is:

$X = 2\pi f C^2 P_T K_O 10^{-8}$, with f = frequency of supply,
C = series conductors of the stator winding.

3. Calculation of magnetizing permeance.

(*a*) The gap constant. To take account of the fringing at the sides of the teeth, the effective gap length is calculated as $K_1 \delta$, where $K_1 = \lambda' \lambda''/T_c' T_c''$

(*b*) The saturation factor S.F., is defined as the ratio,

$$\frac{\text{ampere turns for gap and magnetic circuit}}{\text{ampere turns for gap only}}$$

which varies from 1.1 to 1.3.

(*c*) Magnetizing permeance $P_M = 0.644\, k_w^2 \dfrac{\lambda L}{P_\delta K_1 (S.F.)}$

4. Magnetizing Reactance and Flux Factors.

(*a*) The magnetizing reactance $X_m = 2\pi f C^2 P_m 10^{-8}$

(*b*) The total no-load reactance $X_o = X_m + x_1$
x_1 = leakage reactance of the stator winding
$\cong (1/2)\ X$ total; on the assumption that x_1 equals x_2.
Then $X_o = 2\pi f C^2 P_o 10^{-8}$, and $P_o = P_m + (1/2)\ P_T$.

(*c*) Let $K_p = X_m/(X_m + x_1)$ primary flux factor
$K_s = X_m/(X_m + x_2)$ secondary flux factor
$K_r = K_p K_s$ resultant flux factor
$K_r = (X_o - X)/X_o = (P_o - K_o P_T)/P_o$

By the use of these factors, the presence of the magnetizing branch, connected between x_1 and x_2 is considered by assuming that X is not the simple sum of primary and secondary leakage reactances but instead

$X = x_1 + K_s x_2$, or $x_1 + \sqrt{K_r}\ x_2$

and $x_1 = x_2 = X\ (1 - \sqrt{K_r})/(1 - K_r)$

5. Resistance of the Stator Winding. The winding resistance depends upon the number of conductors, the average conductor length, the wire size and the number of paths in which the winding is connected.

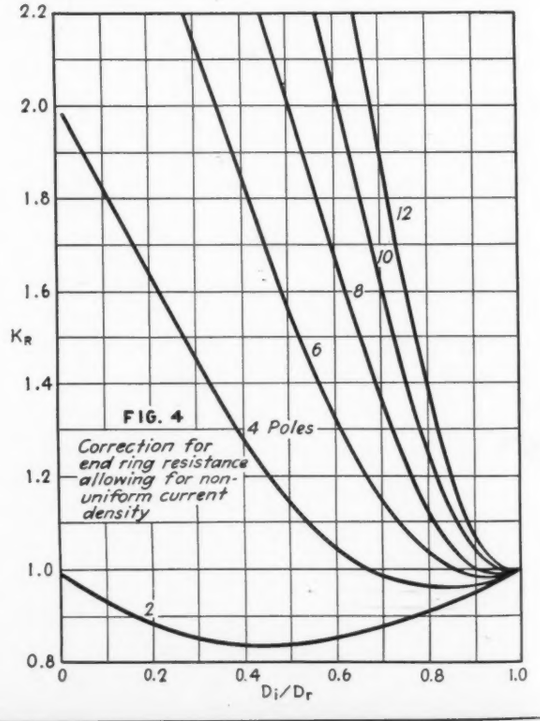
(*a*) Mean length of one conductor, concentric winding, for each coil under one pole:
$l_c = [4(D + \text{tooth length})\ (\text{Teeth inclosed})/S_1] + L$
D = the stator inside diam. in in.
Consider the greatest number of conductors in any slot as unity, and let a lesser number be represented by an appropriate decimal fraction.
Multiply the mean length of one conductor in a coil by the corresponding "decimal fraction of coil." Repeat for each coil and divide the sum of the products by the sum of the "fractions of coils" under one-half pole.

(*b*) Resistance, first method:
Resistance of stator winding $r_1 = (l_c C)/Am$ at 60 deg. C
A = area of one conductor in circular mils.
m = number of paths

(*c*) Resistance, second method: $r_1 = (lc\ C^2)/(A_s\ k\ S')$
A_s = area of the slot in circular mils

$$k = \text{space factor} = \frac{\text{area of copper in slot}}{\text{area of slot}}$$

$A_s k$ = effective or useful slot area

To calculate S', effective number of full stator slots, let the greatest number of conductors in one slot be unity and let each lesser number be represented by a decimal fraction. Add all under one pole and multiply by number of poles.

6. Resistance of the Rotor Winding.
Resistance of a squirrel cage, in stator terms, at 60 deg. C.
$r_2 = [(l_2 k_b/A_b S_2) + (2 D_r k_r K_r/\pi P^2 A_r)]\ 2 c^2 kw^2$
l_2 = bar length in inches.
If the bars are skewed, replace l_2 by $\sqrt{L^2 + S_k^2}$
S_k = the rotor bar skew in inches,
k_b = resistivity of bar material ÷ resistivity of copper
A_b = area of each bar in circular mils
D_r = mean diam. at which bars enter end ring
D_i = inside diam. of end ring in in.
k_r = resistivity of end ring material ÷ resistivity of copper
A_r = area of one end ring section in circular mils
K_r = a correction factor for ring dimensions, see Fig. 4, which makes allowance for non-uniform current density.